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MEMOIRS AND PROCEEDINGS

OF THE

MANCHESTER LITERARY & PHILOSOPHICAL SOCIETY.

(MANCHESTER MEMOIRS.)

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NOTE.

The authors of the several papers contained in this volume are themselves accountable for all the statements and reasonings which they have offered. In these particulars the Society must not be considered as in any way responsible.

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Manchester Memoirs, Vol. xlix. (1904), *No.* **1.**

I. On the Presence of Arsenic in the Body and its Secretion by the Kidney.

By WILLIAM THOMSON, F.R.S.E., F.I.C.

Read April 26th, 1904. Received July 26th, 1904.

At a recent meeting of the Society of Chemical Industry Mr. E. T. Battenshaw told me that arsenic existed in Urine in comparatively large quantities.

I made some experiments and satisfied myself that the kidney secretion of people living in Manchester certainly did contain arsenic, and I have extended the research to find, if possible, the source of the contamination, having got rid of the difficulty of being certain that every particle of the zinc employed in the Marsh-Berzelius apparatus was free from arsenic by employing the electrolytic method devised by me (*Memoirs and Proceedings of The Manchester Literary and Philosophical Society*, Vol. 48, Part III. (Session 1903-1904)) which gives special value to the results because one can be sure that any minute quantities of arsenic found are really contained in the substances examined and do not come from the reagents.

The estimations of arsenic in urine were made by taking 50 cubic centimetres of the sample and adding to it a mixture of 5 c.c. of strong sulphuric acid and 10 c.c. of nitric acid both purified and arsenic-free; these were boiled down in a Jena glass flask* of 200 c.c. capacity till the liquid began to darken, when a few c.c. more of nitric were added, this being repeated until the liquid was colourless, when the whole was heated till white fumes of

* These flasks were previously tested by boiling in them pure strong sulphuric and nitric acids, and finding that the remaining sulphuric acid was free from any trace of arsenic when submitted to the electrolytic test.

October 5th, 1904.

vaporised sulphuric acid filled the flask. A few drops of nitric acid added to the very hot sulphuric acid quickly destroy any remaining organic matter, leaving the arsenic present in the 5 c.c. of clear sulphuric acid: 10 c.c. of pure water were then added and this was evaporated till white fumes again appeared in the flask when it was ready for transferring to the electrolytic apparatus after being diluted with 10 c.c. of pure water, all nitrous compounds having been thus removed, the flask being rinsed with 5 c.c. of pure water.

The electrolytic apparatus is connected up so that the current enters at the platinum anode and leaves at the zinc kathode, 10 c.c. of dilute sulphuric acid (1 part H_2SO_4 7 parts H_2O) are placed in the annular space containing the platinum anode and 10 c.c. of acid (1 of acid to 19 of water) put into the porous pot containing the zinc kathode. The current (3 to 3¼ amps.) is then turned on and in five minutes the apparatus will be full of hydrogen, and the gas issuing from the drawn-out hard glass tube may then be ignited. The tube is then heated for an inch from the drawn-out portion by a flat Bunsen flame, a small piece of platinum wire gauze being wrapped round the tube at the drawn-out portion, the one end of which is heated to redness by the end of the flame, the other end of the gauze keeping the drawn-out portion of the tube hot to within 1½ to 2 mm. from the wet tissue paper at which the mirror is to be deposited. The suspected solution is introduced into the porous pot, and washed in with 5 c.c. of pure water. The test is then allowed to proceed for 35 minutes after the introduction of the suspected liquor, the tube containing the mirror is then sealed off in hydrogen, labelled and mounted for reference.*

* In using a zinc kathode care should be taken that the strength of acid does not exceed 1 of acid in 5 of water, otherwise the full-sized mirror is not obtained; with a pure tin kathode this precaution is unnecessary.

Professor W. J. Sinclair, M.D., was good enough to procure for me six samples of urine from patients in the Manchester Southern Hospital, all of which shewed the presence of arsenic (see *Plate I., Fig.* 1)* two, each contained amounts which I estimated at the $\frac{1}{400}$th of a grain per gallon, two contained about $\frac{1}{1000}$th, one a $\frac{1}{800}$th, and one $\frac{1}{100}$th of a grain per gallon. The last was remarkable, as the woman (age 47), a weaver, had been 13 days in the hospital, had lived on simple food and had taken no medicine during that time.

The source of the arsenic in the body may obviously come from taking food or liquids containing it as an impurity, under these circumstances it seemed of interest to find how rapidly arsenic would be eliminated from the body. The following experiment was therefore made :—

A man (age 24), a teetotaller, took an accurately determined quantity of $\frac{1}{50}$th of a grain of arsenic trioxide in solution on Wednesday, the 20th of April, 1904, at 4 p.m. Previous tests of his urine were made on the 22nd January, 1904, and shewed $\frac{1}{400}$th of a grain per gallon, and on the 18th April, 1904, it shewed $\frac{1}{1000}$th of a grain per gallon, calculated as arsenic trioxide.

The urine was measured, and the amount of arsenic determined in each sample. The arsenic mirrors obtained are shewn in *Plate I., Fig.* 2. One hour after taking the dose six ounces were passed, and the arsenic present had risen to $\frac{1}{800}$th of a grain per gallon, equal to a total quantity of $\frac{1}{16000}$th, or 0·0000625 of a grain.

Assuming the $\frac{1}{50}$th of a grain of As_4O_6 divided into

*The tubes containing the mirrors were mounted on white cardboard about a mm. from the card, so as to give a shadow which would help to shew the outline of the tubes, and would not interfere with the appearance of the mirrors by reflection from the glass. It must be noted, however, that when the tubes contain little or no arsenic mirror, the outline of the tube itself is hardly shewn, whilst its shadow is distinctly seen.

1000 parts, then, after deducting for the normal amount of arsenic trioxide (As_4O_6) contained in the normal urine, the samples collected after the dose was taken contain the following number of parts:—

Passed after	Quantity of the Sample.	Per Gallon.	Total quantity eliminated in Parts of the 1000 Parts taken.
1 hour.	6 ozs.	$\frac{1}{600}$th of a grain.	1·25 parts.
7 hours.	9 „	$\frac{1}{30}$th „ „	90·94 „
16 „	7 „	$\frac{1}{50}$th „ „	41·57 „
19 „	4 „	$\frac{1}{80}$th „ „	14·38 „
23 „	5 „	$\frac{1}{100}$th „ „	14·06 „
Total amount eliminated in 23 hours.....			162·20 parts.

i.e., about 16 per cent. of the total quantity taken. The sixth and last sample was taken 47 hours after taking the dose, and this contained $\frac{1}{1000}$th of a grain of arsenic trioxide per gallon, which was the quantity found previous to making the experiment.

If arsenic can be so rapidly eliminated from the system, it is remarkable how such a large quantity came to be found in the urine of the patient above mentioned, whilst living on simple food during 13 days, and without any recognisable source of pollution.

It occurred to me that the arsenic found in the urine of people who lived simply, and took no alcoholic liquors, must arise from breathing the air of large towns. I therefore asked Dr. Henry Ashby, of Manchester, if he

could arrange for me to have samples from persons staying at the Convalescent Home, near St. Annes-on-the-Sea, where the air is not likely to be polluted. From this institution I received five samples, four of which were free from arsenic to my test, and one contained a trace equal to $\frac{1}{1100}$th of a grain per gallon. Photographs of these mirrors are shewn in *Plate I., Fig.* 3.

Through Dr. J. J. Cox, of Manchester, I obtained three samples from the Northern Hospital for Children in Manchester; two were from children whose diet consisted of bread and milk, and one from a child whose diet was milk alone. The first gave an arsenic mirror equal to $\frac{1}{400}$th of a grain per gallon, the second gave $\frac{1}{1000}$th, and that from the child fed on milk alone was free from arsenic. This seemed to shew that it was possible to get urine free from arsenic in persons living near Manchester, although it was the only arsenic free sample according to my test which I had hitherto obtained.* See *Plate I., Fig.* 1.

I then arranged to get samples from persons living in places in which presumably the air would contain more arsenic than is usual in large towns like Manchester. On a former occasion I tested the soot from a domestic chimney, and found it to contain 1·5 grains of arsenic trioxide per lb., and Mr. Thomas Fairley, of Leeds, found the dust on his book shelves to contain 0·4 grain per lb., and in the dust from the shelves of a shop in a main street in Leeds he found 0·3 grain of arsenic trioxide per lb. The arsenic there found had no doubt come from the burning of coal in the houses and factories in and near the town.

It occurred to me that there should be found

*This freedom from arsenic may be due to the comparatively large quantity of liquid taken, diluting any trace so much that it failed to show by my test.

considerable quantities of arsenic in the urine of persons living in St. Helens, where glass manufacture is carried on, because arsenic trioxide is used for stirring the molten glass, by its vapour passing in bubbles through the molten glass, and large quantities of it escape into the atmosphere. I consequently communicated with Dr. Edward Casey, of St. Helens, and he very kindly procured and sent to me five samples, although he explained to me that the glass works were not in operation at this time. The results shew however that all the samples contain considerable quantities of arsenic. See *Plate I., Fig.* 3.

No. 1 was from a man, age 59, who had been "gassed" by fumes from iron pyrites, the sample contained $\frac{1}{300}$th of a grain per gallon.

No. 2, age 37, surgeon, who lives near a glass works, $\frac{1}{400}$th of a grain per gallon.

No. 3, age 61, engaged at copper works. Never takes beer, $\frac{1}{400}$th of a grain.

No. 4, age 31, clerk, teetotaller, $\frac{1}{400}$th of a grain.

No. 5, age 23, lives near glass and chemical works, $\frac{1}{300}$th of a grain.

I then communicated with Dr. Ebenezer Davies, the Medical Officer of Health of Swansea, where large metallurgical operations are carried on and where presumably considerable quantities of arsenic exist in the air. He and his friend Dr. T. M. J. Powell very kindly obtained six samples for me. The results from which are shewn in *Plate II., Fig.* 1.

No. 1, age 52, spelter furnace man. Mixture of this with an equal volume of No. 6 gave $\frac{1}{150}$th of a grain per gallon.

No. 2, age 26, abstainer, $\frac{1}{90}$th.

No. 3, age 24, $\frac{1}{200}$th.

No. 4, age 24, $\frac{1}{700}$th.

No. 5, age 32, $\frac{1}{80}$th. All these four were labourers in nickel and cobalt works.

No. 6, age 38, copper smelter ($\frac{1}{150}$th, 1 part of this sample was mixed with an equal volume of No. 1).

Dr. P. Bennett, of Sheffield, was good enough to send me five samples, the results from which are shewn in *Plate II., Fig.* 1.

*No. 1, age 42, collier, moderate drinker, lived in district 6 years, $\frac{1}{100}$th of a grain per gallon.

No. 2, age 53, pearl grinder, moderate drinker, lived in district all his life, $\frac{1}{200}$th.

*No. 3, age 60, labourer, moderate drinker, lived only in this district.

*No. 4, age 44, collier, moderate drinker, lived in district 20 years.

No. 5, age 35, shop assistant, lived in district 10 years, $\frac{1}{1000}$th.

Lastly it suggested itself to me that the urine of people who live in districts where only peat is burned should be free from arsenic. I therefore wrote to my friend, Mr. A. A. Chisholm, Procurator Fiscal, of Lochmaddy, Hebrides, who sent me six samples from six different persons who live in houses where only peat is burned. All these were absolutely or practically free from arsenic. See *Plate II., Fig.* 2.

MILK.—It seemed probable that, if the secretions from the kidneys contain arsenic, milk might also contain it, and I sent to two different shops in Manchester and purchased some, I also obtained one sample from Chorlton-

* There was not sufficient of 3 and 4 together for the test, so that 14 parts of No. 1, 13 parts of No. 3, and 23 parts of No. 4 were taken, and these gave $\frac{1}{100}$th of a grain per gallon.

cum-Hardy, in Manchester, and one from Bramhall, near Manchester.

Mr. Chisholm also sent me two samples from his own cows. The results obtained from these samples are shewn in *Plate II., Fig.* 3.

No. 1 contained less than $\frac{1}{1000}$th. Nos. 2, 3, and 4 contained about $\frac{1}{500}$th each: all these were bought in Manchester. No. 5, from Chorlton-cum-Hardy, contained about $\frac{1}{1000}$th. No. 6, from Bramhall, contained $\frac{1}{450}$th of a grain per gallon; whilst the two samples from Lochmaddy, in the Hebrides, showed no trace of arsenic mirrors.

As to sources of pollution besides contaminated air, I thought it probable that steaks and chops grilled over a coke fire would contain some arsenic from the fumes of the coke. I therefore obtained from the Reform Club, through Mr. F. Scott, a steak which was divided into two parts, one left raw, the other "well done" over the grid. I cut 5 grammes from each through the pieces; the raw steak was free from arsenic, and the grilled steak contained a trace which was barely visible, amounting to not more than the $\frac{1}{2000}$th of a grain per lb. See *Plate III., Fig.* 1.

Thinking the arsenic might be adhering to the outside of the steak, I cut 5 grammes from the outside surfaces, but found it contained but little more than the portion which I cut across. It is satisfactory, therefore, to feel that the operation of grilling practically does not contaminate the meat with arsenic from the coke. This is probably due to the fact that there is a rapid current of air between the fire and the meat, which no doubt efficiently carries away the arsenic fumes and dust from the coke.

I next examined four different brands of cigarette paper, and found all to contain arsenic.

No. 1, marked "Sirdar," contained $\frac{1}{1000}$th of a grain per lb.

No. 2, marked "J. O. B," contained $\frac{1}{300}$th of a grain per lb.

No. 3, marked "The Handy," contained $\frac{1}{300}$th of a grain per lb.

No. 4, marked "Tarlene" (which has a preparation applied to it), contained $\frac{1}{250}$th of a grain per lb.

These amounts, when taken on a single sheet or on a dozen sheets of cigarette paper, are quite inappreciable. The results are shewn in *Plate III.*, *Fig.* 1.

Gautier, of Paris, has stated that arsenic is a constituent of the thyroid gland. Through Dr. J. J. Cox I obtained the thyroid gland of an animal, and also the thymous gland. I took 5 grammes of the former and 10 grammes of the latter, expecting to find a much larger quantity of arsenic in the thyroid gland. I found, however, that weight for weight, they both contained about the same quantity of arsenic, which amounted to not more than the $\frac{1}{1000}$th of a grain per lb. See *Plate III.*, *Fig.* 1.

One could hardly say that the trace of arsenic found in either was sufficient to speak of that element as being a constituent part of either gland.

It seemed, however, interesting to determine whether the same result could be obtained from the thyroid gland of a human subject. I accordingly obtained the whole gland, which weighed about 18 grammes. I took 15 grammes of it. The body from which it was taken was that of a man about 65 years of age, an abstainer, who died of heart disease. The thyroid gland contained only a minute quantity of arsenic, $\frac{1}{1500}$th of a grain per lb.

There is, however, this to be said, that when 15 grammes of other organs of the same body were tested, they proved to be free from arsenic. Thus the spleen, liver, heart-muscle, kidney, and rib bone were free from arsenic by my test, but it was remarkable to note that the lung contained considerably more arsenic than the thyroid gland, viz., $\frac{1}{900}$th, and the hair contained a great deal more than either, viz., $\frac{1}{125}$th of a grain per lb., whilst the brain contained a very minute trace.

All the experiments were made by heating the portions of the various organs with sulphuric and nitric acid. The organic matter which was most resistant to oxidation being finally removed by dropping strong nitric acid into the dark-coloured strong sulphuric acid solution heated to the point of liberating white fumes, the resulting arsenic being finally contained in the 5 c.c. of strong colourless sulphuric acid originally used, the whole of the nitric acid having been finally removed by treating the resulting sulphuric acid with water and evaporating the water and nitric compounds to the point when the sulphuric acid gave off heavy white fumes. The prints of the mirrors obtained are shewn in *Plate III., Fig.* 2.

Ordinary meat and the organs, such as the liver, kidney, spleen, and lung oxidise easily under this treatment, but the tissue of the brain resisted oxidation in a remarkable manner. It evidently differed from other tissues in containing some organic constituent which remained intact in boiling strong sulphuric acid, and only gradually disappeared on frequent treatment of the highly heated acid (whilst giving off white fumes) with strong nitric acid.

I have to thank my assistant, Mr. Samuel Bateman, B.Sc. (Vict.), for the care he has bestowed in carrying out these experiments with me.

FIG. 1.

Urines from patients in Manchester Hospitals.

Arsenic mirrors obtained from 50 c.c.

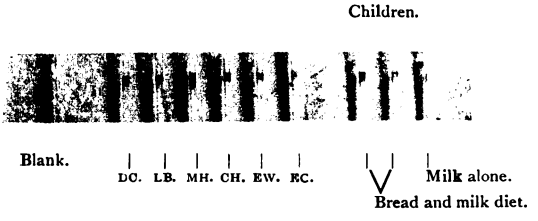


FIG. 2.

Effect on Urine of one dose of $\frac{1}{50}$ *grain* As_4O_6 *taken by a man, age 24—teetotaller—at 4 p.m., Tuesday, 19th April, 1904.*

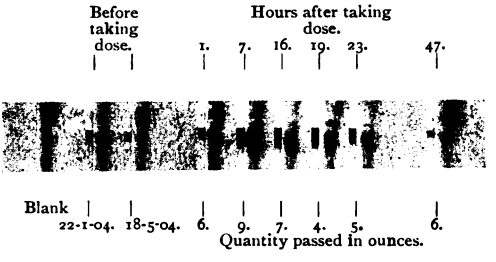


FIG. 3.

URINES.

Arsenic mirrors obtained from 50 c.c.

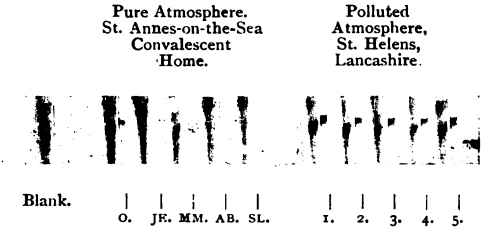

Pure Atmosphere. St. Annes-on-the-Sea Convalescent Home.
Polluted Atmosphere, St. Helens, Lancashire.
Blank.
O. JE. MM. AB. SL.
1. 2. 3. 4. 5.

FIG. 1.

URINES.

Arsenic mirrors obtained from 50 c.c.

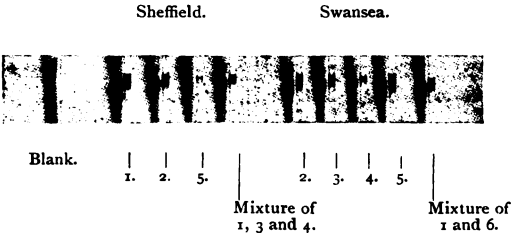


FIG. 2.

URINES.

Arsenic tests on 50 c.c.

From Lochmaddy—Hebrides.

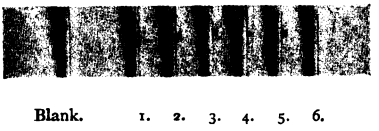


FIG. 3.

MILKS.

Arsenic mirrors obtained from 50 c.c.

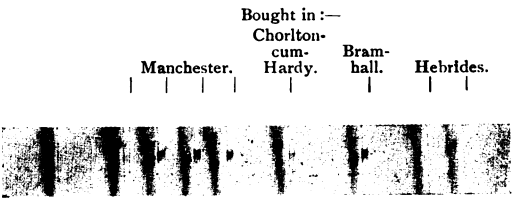


FIG. 1.

MISCELLANEOUS.

Arsenic mirrors obtained from 5 grams.

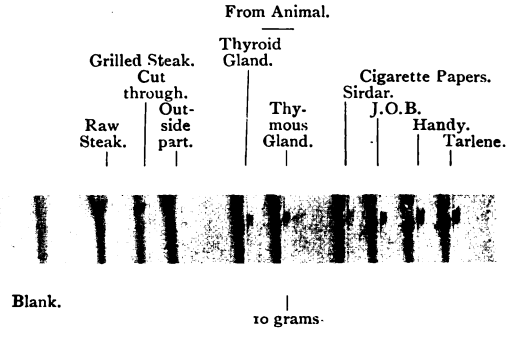
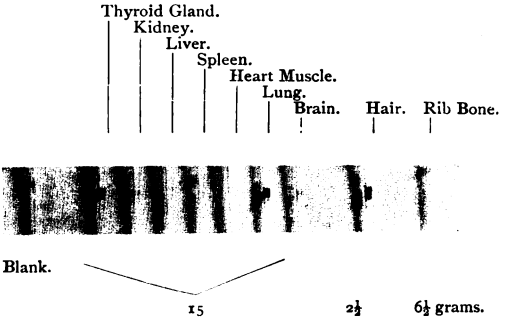


FIG. 2.

Arsenic contained in the different tissues of a man, age about 65— Teetotaller. Died of heart disease.



Manchester Memoirs, Vol. xlix. (1904), *No.* 2.

II. Note on the Electrolytic Preparation of Titanous Sulphate.

By W. H. EVANS, B.Sc.

(*Communicated by Mr. R. S. Hutton, M.Sc.*)

Received and read November 1st, 1904.

Despite the important applications of the titanous salts during the last few years, and the fact that they are now prepared technically by electrolysis,* no data have been published to show the influence upon the yield of varying the conditions of working. It seemed, therefore, of some interest to investigate the effect of the current density, concentration of solution and temperature at which the electrolysis is carried out, upon the course of this electrolytic reduction. Up to the present only titanium sulphate has been dealt with.

In the earlier work the solutions were electrolysed in a beaker, with a porous pot to separate the anode from cathode chambers, but it was soon found that the solution of titanous sulphate, despite the very powerful reducing properties of this compound, is quite stable, and that very good yields could be obtained without the use of any diaphragm. Provided the current density at the anode is kept fairly high, the oxygen is evolved without effecting any marked oxidation of the titanous salt. This, of course, considerably simplifies the preparation, and in all the later work the electrolysis was carried out in a beaker or vat in which the electrodes were suspended at some distance

* Howard Spence and P. Spence and Sons Brit. Patents, Nos. 18,108, and 16,238 of 1902.

apart. Moreover, the P.D. required is much lower owing to the smaller resistance of the cell (2·5 to 3·5 volts instead of 4 to 5 volts).

Effect of Varying the Current Density.

With a solution containing 40·8 gms. titanium sulphate per litre in a beaker containing 400 c.c., with a current of 3·5 amperes = (14 amperes per 100 sq. cms.), the yield at 20 minutes after starting was 31 per cent., after 33 minutes 22 per cent.

With the same solution, but with only 1·7 amperes (= 6·8 amperes per 100 sq. cms.), the yield at corresponding times was 62 and 50 per cent. respectively. That the yield falls rapidly with increase of current density was fully borne out by the results of a series of preliminary experiments, using a porous pot.

Influence of Temperature.

It was found that by raising the temperature at which electrolysis was carried out the yield could be considerably increased. The comparative experiments were arranged by connecting two electrolytic cells containing the same solutions (81·6 gms. $Ti(SO_4)_2$ per litre) in series. One cell was kept at 70°C., the other as near 0°C. as possible. At the higher temperature, with a current density of 4·5 amperes per 100 sq. cms., the yield could be kept above 70 per cent. until quite half of the titanium sulphate had been reduced.

In the cold solution, on the other hand, the yield was only about 45 per cent. of the theoretical; the difference in the two cases was very clearly seen in the fact that there was no visible evolution of hydrogen at the cathode in the hot solution, whereas in the cold a considerable amount of hydrogen was given off.

Effect of Concentration.

In the preliminary experiments, using a porous pot to separate the anode from the cathode, the influence of concentration within the limits of 85 to 17 gms. of titanium sulphate per litre was very evident, for with a current density of about 7 amperes per 100 sq. cms., and a temperature of 15° to 17°C., the yields were as follows:—

(1) Solution containing 85 gms. $Ti(SO_4)_2$ per litre, 75 per cent.

(2) Solution containing 42·5 gms. $Ti(SO_4)_2$ per litre, 33 per cent.

(3) Solution containing 17 gms. $Ti(SO_4)_2$ per litre, 2·2 per cent. of the theoretical for the current used.

In comparative experiments in which platinum electrodes were substituted for those of lead no very great difference in yield could be observed, possibly with lead better results were obtained.

The estimation of the amount of titanous salt obtained was carried out by titrating a small quantity of the solution from the cell with standard permanganate, after warming to 60° or 70°C.

In all the experiments the cathode solution was well stirred, either by a mechanical stirrer or by passing a current of some inert gas.

Manchester Memoirs, Vol. xlix. (1904), *No.* 3.

III. On the Determination of Wave-lengths in the extreme Ultra-violet Portion of the Spectrum.

By H. MORRIS-AIREY, M.Sc.

Received and read November 29th, 1904.

The development of the study of the ultra-violet portion of the spectrum was in its earliest stages closely connected with the progress of photography and the discovery of fluorescence.

The first important contribution to the subject was made by Edmund Becquerel in 1842, in a work containing observations of the effect of sunlight on the recently discovered silver chloride plates. This publication contained the first account of systematic observations of spectra in the region beyond the visible violet. The prism and lenses of the spectroscope which Becquerel used were, however, constructed of glass, so that the shortest wave-length which he was able to photograph could not have been less than 3,100 Å, the absorption of glass being already very strong at this region.

This property of glass seems to have been first recognised by Stokes, who, in the period 1852 to 1862, used quartz for the optical parts of his spectroscopes, with the result that he was able to detect radiations far beyond the Fraunhofer line P in the spectrum of sunlight.

The spectral lines were observed by allowing the spectrum to fall on a screen made of some fluorescent material placed in the eyepiece of the telescope.

The experiments of Piazzi Smyth on the increased range of the spectrum of sunlight when photographed at high altitudes showed that the atmosphere absorbed and kept back the ultra-violet light to a marked degree. To

avoid this absorption Stokes adopted as his source of light an electric spark between aluminium electrodes, and was then able to observe spectral lines as low as 1,852 Å. Miller, who was investigating ultra-violet spectra at about the same time, was unable to photograph light with a wave-length of less than 2,024 Å.

The result of this failure of photographic methods was that subsequent investigators, Soret, Sarasin, and others, relied solely on the fluorescent screen method, until Cornu discovered that photographic plates could be prepared which would register the last spectral line observed by Stokes. An important factor in his success was that he recognised the strongly absorbing influence of air, and accordingly designed his spectrograph so that the air path traversed by the light in passing from the source to the photographic plate was comparatively short.

The aluminium double line at 1852 Å remained the boundary of the violet end of the spectrum until about 1889, when Victor Schumann, of Leipzig, began his classical work. He soon rejected the conventional quartz spectrograph in favour of one constructed with fluorspar prism and lenses. It had already been found that the white transparent variety of this mineral was at least as transparent as quartz for ultra-violet light, and in Schumann's hands it soon proved to be very superior to quartz in this respect. An elaborate spectrograph * was designed and constructed by Schumann, which could be exhausted by means of a mercury pump, and all the necessary adjustments of a spectrometer could be carried out without admitting air to the apparatus. Schumann discovered that ordinary photographic plates were quite useless for ultra-violet work, as the gelatine in which the particles of silver bromide and iodide are embedded

* V. Schumann, *Wiener Berichte*, 1893.

absorbs the short wave-lengths. Using plates containing gelatine as a substratum, leaving the sensitive silver salts exposed to the direct action of the light,* Schumann was able to announce in 1893 the discovery of lines in the spectrum of hydrogen, having a wave-length which he estimated at about 1,000 Å. Owing to our imperfect knowledge of the dispersion of fluorspar for these short waves, it is impossible to determine accurately the wave-length in a spectrum produced by means of a fluorspar prism.

No further attempts to measure these waves seemed to have been made up to 1900. This is regrettable, because it is probably in this region that a clue to the complicated relationship of spectral lines will be found. For example, the failure of Kayser and Runge to discover series in the spectra of many elements may be due to the fact that in these cases the series lie in the inaccessible ultra-violet. It seemed, therefore, a grateful task to undertake measurements in this region, and at the suggestion of Professor Kayser I attempted this in 1901 with a concave grating.

The apparatus was disposed in the manner indicated in *Fig.* 1.

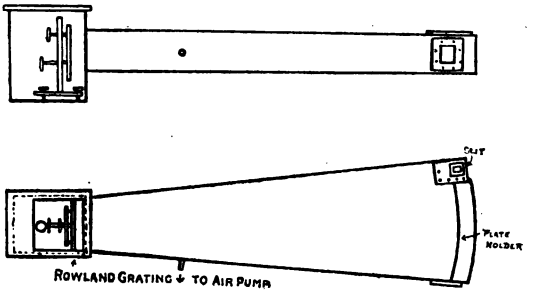


Fig. 1.

* *Wien. Berichte*, 1893.

A Rowland concave grating of 1 metre radius was mounted with a slit and camera in a substantial box of "Rotguss." The adjustments could be carried out through small manholes in the cover of the box. The camera was so situated that half the plate was covered with the lines extending from 4,500 to 2,800 Å. The focus could then be adjusted with the ordinary iron arc light, and any shorter wave-lengths would be in focus on the plate down to 1,100 Å and their value determined to within ·1 Å by applying the scale found from the larger waves.

Considerable difficulty was experienced in obtaining a good vacuum in spite of the close texture of the metal of which the box was cast, and it was only after enclosing the whole apparatus in a cement made by mixing asbestos powder with water glass that the box could be exhausted to a pressure of $\frac{1}{10}$ mm. of mercury.

The photographic plates were prepared according to an improved recipe which Schumann was kind enough to communicate privately.*

The source of light was an electric spark produced between aluminium electrodes by the discharge of a Leyden jar connected to an induction coil capable of giving a 15 inch spark in air.

The spark gap was situated about 5 cm. from the slit, which it illuminated through a small window of fluorspar at the end of the box. Afterwards, to eliminate the effect of the 5 cms. of air, the electrodes were enclosed in a tube of hydrogen, which is very transparent, as Schumann found. Vacuum tubes were also tried placed directly on to the box without any fluorspar intervening. The whole apparatus was filled with hydrogen, and exhausted to a pressure of 1 mm. of mercury. The double line 1,860, 1,852 Å appeared

*Since published in *Wied. Annalen*, 1902.

strongly, but beyond this nothing but a trace of a continuous spectrum appeared on the photographs. I concluded that the failure was due to insufficient reflection of the short waves from the surface of the grating.

The only chance of success seemed to lie in using a transmission grating ruled on some transparent substance. Through the generosity of Mr. Hans Hauswaldt, of Magdeburg, this was made possible.

A plane-grating having 500 lines per mm. was ruled by Rowland on a plate of transparent fluorspar of 4 cms. edge, and $\frac{1}{2}$ cm. thickness.

A vacuum spectrograph, similar to the one used by Schumann, was built for Mr. Hauswaldt by Fuess, of Steglitz. The camera and slit were exact reproductions of the corresponding parts of Schumann's apparatus, but the body of the instrument was modified to suit the method of using the grating. *Fig.* 2 is an outline of the design of

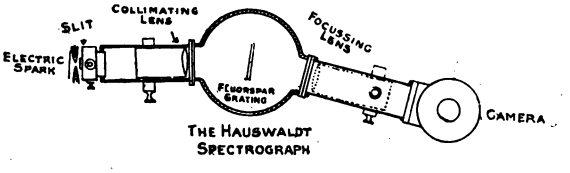


Fig. 2.

the apparatus. The collimator and camera tube were fixed relative to one another at a small angle, and the grating could be rotated and its position read off by means of two verniers on a graduated circle attached to it.

The slit could be adjusted, and the collimating and focussing lenses racked out without disturbing the vacuum.

The plate-holder could be raised, enabling ten photographs to be taken on one plate, without admitting any

air. Another adjustment which was found very necessary, viz., inclining the plate to counteract the aberration of the lenses for different wave-lengths, could also be carried out in vacuo.

These adjustments were, however, practically a source of weakness to the instrument, as they involved the perfect fitting of over thirty ground surfaces to maintain the vacuum.

A sudden rise or fall in the temperature of the laboratory frequently involved taking the whole instrument to pieces for relubrication of the sliding surfaces before the apparatus could be exhausted.

Using the discharge from a Leyden jar charged by the 15 inch induction coil, I was able to photograph a group of lines lying well beyond 1,852 Å.

To obtain a more powerful source of light, the electric arc between two iron rods in vacuo was produced directly in front of the slit. However, intense as the radiation was in the ordinary ultra-violet, nothing could be detected beyond 1,852.

Vacuum tubes were again tried, with little success, and finally a very powerful induction coil, built by Klingelfuess, of Basel, was placed at my disposal by Professor Kayser.

This coil, when fed with a current of 50 ampères interrupted by the Wehnelt electrolytic interrupter, easily gave a spark of 1 metre length and about 2 cms. thickness in air.

This spark was reduced by a large plate condenser to about 1½ cms. length, and allowing this to glide across the face of the fluorspar window in front of the slit, so as to reduce the air gap to a minimum, I finally succeeded in obtaining lines in the aluminium spectrum extending over nearly 200 Å beyond the previous limit.

The wave-lengths were determined in the following manner:—

When the grating is situated symmetrically with respect to the collimating and camera tubes, we have

$$2d\sin\epsilon = 2n\frac{\lambda}{2} \quad \text{(see } \textit{Fig.} \text{ 3)},$$

where d is the distance between consecutive lines on the grating, 2ϵ the angle between the axes of the collimator and camera tube, and λ is the wave-length of the particular light which happens to fall in the centre of the camera; n is a constant equal to unity if the spectrum is of the first order.

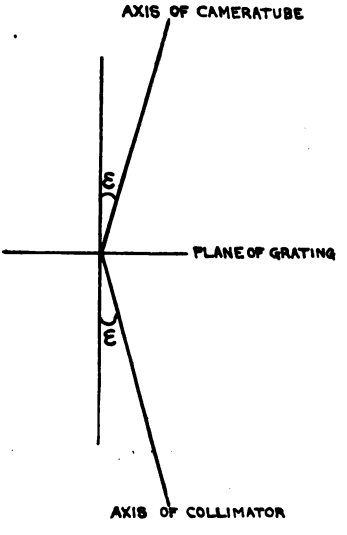


Fig. 3.

If the grating is rotated through an angle δ_1, we shall have

$$d\{\sin(\delta_1 + \epsilon) - \sin(\delta_1 - \epsilon)\} = n\lambda_1 \quad \text{(see } \textit{Fig.} \text{ 4)},$$

or

$$2d\cos\delta_1\sin\epsilon = n\lambda_1,$$

λ_1 being the wave-length of the light which now falls at the centre of the camera.

For any other rotation, say δ_2, we have

$$2d \cos \delta_2 \sin \epsilon = n\lambda_2$$

$$\therefore \frac{\cos \delta_1}{\cos \delta_2} = \frac{\lambda_1}{\lambda_2}$$

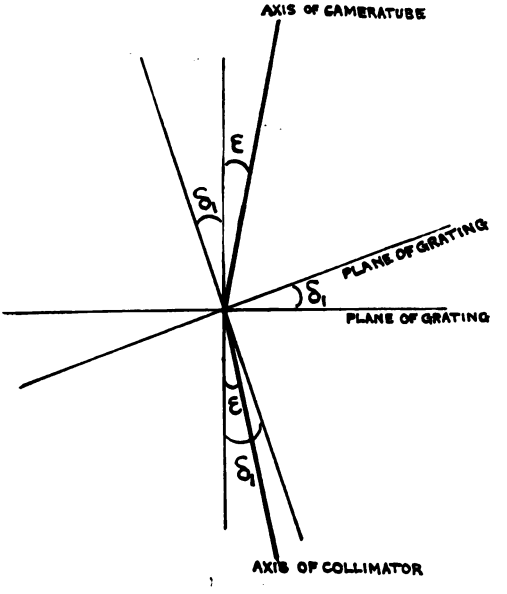


Fig. 4.

Evidently it is immaterial in which direction we rotate the grating. There will be therefore two positions of the grating, equally inclined to the position of symmetry in which any wave-length λ_1 can be brought to the centre of the camera. The angle between the two positions is $2\delta_1$, and it is more convenient to measure this than δ_1.

The fiducial mark at the centre of the camera was produced by a fine steel point fixed in the camera, whose shadow appeared on every photograph. The grating was

moved by a micrometer screw between successive photographs, and after perhaps twenty or thirty attempts a photograph would be secured with the shadow of the point exactly on the centre of the line to be measured.

The reading of the position of the grating was noted, and the line again photographed in the same manner, with the grating rotated into the second position. The difference of the readings for the two positions of the grating gave $2\delta_1$.

Each line was determined relative to the aluminium line of wave-length 1862·8 Å as λ_1. The wave-lengths of the four sharpest lines were

1785,
1741,
1709,
1693.

From these lines the wave-lengths of all the lines photographed by Schumann down to 1690 Å can be found by interpolation, and several metal spectra tested for series.

I wish to express my gratitude to Professor Kayser, of Bonn, in whose laboratory the experiments were carried out, for his valuable advice, for the invariable interest which he took in the work, and for the loan of the costly apparatus which he placed at my disposal.

Most especially are my thanks due to Herr Hans Hauswaldt for the use of his unique spectrograph and fluorspar-grating, without which it would have been impossible to carry out the research.

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Manchester Memoirs, Vol. xlix. (1905), *No.* 4.

IV. On the Rigidity of Gelatine.

By H. MORRIS-AIREY, M.Sc.

Received and read January 24th, 1905.

The material used in the following experiments is a jelly made by dissolving gelatine* in warm water. On cooling, the mass becomes an elastic solid which has some interesting properties.

For all ordinary pressures (*i.e.*, up to 5 or 6 atmospheres) the material shows no diminution in volume but it is very easily distorted by tangential stress. This latter property has been made use of in optics by Clerk-Maxwell to exhibit the action of crystalline media on polarised light.

If such a jelly is saturated with a salt solution many of its physical properties, such as velocity of electrolytic ions in it, are approximately the same as those of the aqueous solution of the salt. Consequently jellies of this kind have found application in experiments where convection currents within the salt solution were to be avoided.

An interesting property is mentioned by Mactear.† A crystal embedded in a salt solution jelly, continues to grow as a single crystal developing into a very symmetrical specimen, while in an ordinary aqueous solution this is hindered by the formation of other lesser crystals. He attributes the formation of the very perfect selenite crystals found in plastic clay to this cause.

It was in connection with the use of jelly plugs in diffusion experiments that the method of measuring the rigidity of gelatine solutions was suggested.

* That known commercially as "Nelson" leaf gelatine was used.

† *Transactions of Inst. Mining and Metallurgy*, XII., 1902, p. 132.

February 16th, 1905.

A Rowland concave grating of 1 metre radius was mounted with a slit and camera in a substantial box of "Rotguss." The adjustments could be carried out through small manholes in the cover of the box. The camera was so situated that half the plate was covered with the lines extending from 4,500 to 2,800 Å. The focus could then be adjusted with the ordinary iron arc light, and any shorter wave-lengths would be in focus on the plate down to 1,100 Å and their value determined to within ·1 Å by applying the scale found from the larger waves.

Considerable difficulty was experienced in obtaining a good vacuum in spite of the close texture of the metal of which the box was cast, and it was only after enclosing the whole apparatus in a cement made by mixing asbestos powder with water glass that the box could be exhausted to a pressure of $\frac{1}{10}$ mm. of mercury.

The photographic plates were prepared according to an improved recipe which Schumann was kind enough to communicate privately.*

The source of light was an electric spark produced between aluminium electrodes by the discharge of a Leyden jar connected to an induction coil capable of giving a 15 inch spark in air.

The spark gap was situated about 5 cm. from the slit, which it illuminated through a small window of fluorspar at the end of the box. Afterwards, to eliminate the effect of the 5 cms. of air, the electrodes were enclosed in a tube of hydrogen, which is very transparent, as Schumann found. Vacuum tubes were also tried placed directly on to the box without any fluorspar intervening. The whole apparatus was filled with hydrogen, and exhausted to a pressure of 1 mm. of mercury. The double line 1,860, 1,852 Å appeared

*Since published in *Wied. Annalen*, 1902.

strongly, but beyond this nothing but a trace of a continuous spectrum appeared on the photographs. I concluded that the failure was due to insufficient reflection of the short waves from the surface of the grating.

The only chance of success seemed to lie in using a transmission grating ruled on some transparent substance. Through the generosity of Mr. Hans Hauswaldt, of Magdeburg, this was made possible.

A plane-grating having 500 lines per mm. was ruled by Rowland on a plate of transparent fluorspar of 4 cms. edge, and $\frac{1}{2}$ cm. thickness.

A vacuum spectrograph, similar to the one used by Schumann, was built for Mr. Hauswaldt by Fuess, of Steglitz. The camera and slit were exact reproductions of the corresponding parts of Schumann's apparatus, but the body of the instrument was modified to suit the method of using the grating. *Fig.* 2 is an outline of the design of

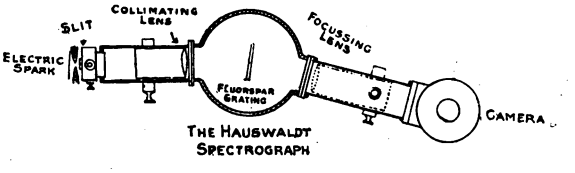

Fig. 2.

the apparatus. The collimator and camera tube were fixed relative to one another at a small angle, and the grating could be rotated and its position read off by means of two verniers on a graduated circle attached to it.

The slit could be adjusted, and the collimating and focussing lenses racked out without disturbing the vacuum.

The plate-holder could be raised, enabling ten photographs to be taken on one plate, without admitting any

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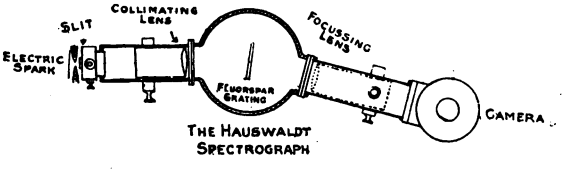

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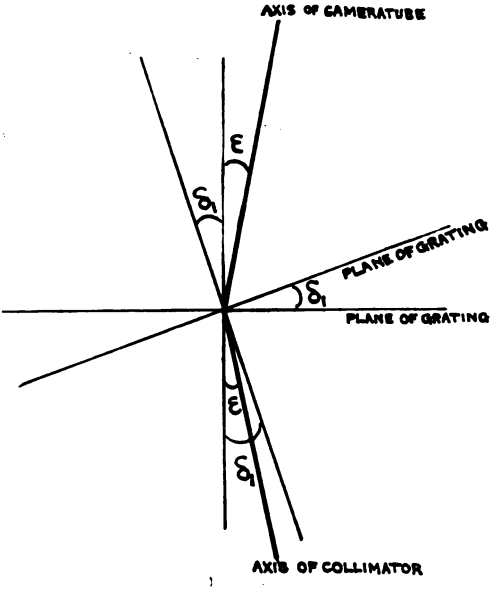
The plate-holder could be raised, enabling ten photographs to be taken on one plate, without admitting any

λ_1 being the wave-length of the light which now falls at the centre of the camera.

For any other rotation, say δ_2, we have

$$2d \cos \delta_2 \sin \epsilon = n\lambda_2$$

$$\therefore \frac{\cos \delta_1}{\cos \delta_2} = \frac{\lambda_1}{\lambda_2}$$



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Evidently it is immaterial in which direction we rotate the grating. There will be therefore two positions of the grating, equally inclined to the position of symmetry in which any wave-length λ_1 can be brought to the centre of the camera. The angle between the two positions is $2\delta_1$, and it is more convenient to measure this than δ_1.

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Most especially are my thanks due to Herr Hans Hauswaldt for the use of his unique spectrograph and fluorspar-grating, without which it would have been impossible to carry out the research.

λ_1 being the wave-length of the light which now falls at the centre of the camera.

For any other rotation, say δ_2, we have

$$2d \cos \delta_2 \sin \epsilon = n\lambda_2$$

$$\therefore \frac{\cos \delta_1}{\cos \delta_2} = \frac{\lambda_1}{\lambda_2}$$

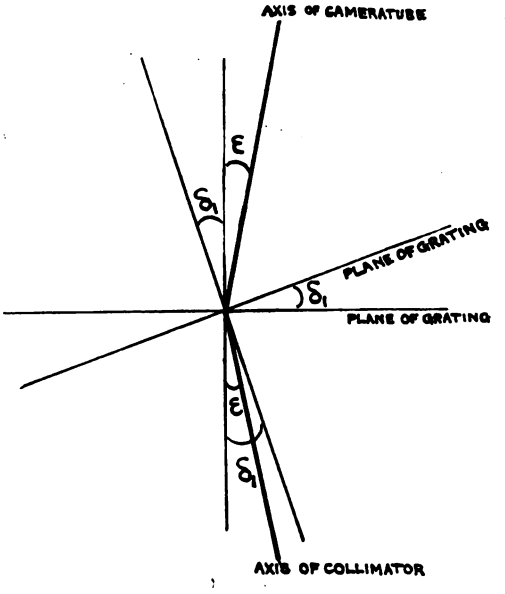

Fig. 4.

Evidently it is immaterial in which direction we rotate the grating. There will be therefore two positions of the grating, equally inclined to the position of symmetry in which any wave-length λ_1 can be brought to the centre of the camera. The angle between the two positions is $2\delta_1$, and it is more convenient to measure this than δ_1.

The fiducial mark at the centre of the camera was produced by a fine steel point fixed in the camera, whose shadow appeared on every photograph. The grating was

moved by a micrometer screw between successive photographs, and after perhaps twenty or thirty attempts a photograph would be secured with the shadow of the point exactly on the centre of the line to be measured.

The reading of the position of the grating was noted, and the line again photographed in the same manner, with the grating rotated into the second position. The difference of the readings for the two positions of the grating gave $2\delta_1$.

Each line was determined relative to the aluminium line of wave-length 1862·8 Å as λ_1. The wave-lengths of the four sharpest lines were

1785,
1741,
1709,
1693.

From these lines the wave-lengths of all the lines photographed by Schumann down to 1690 Å can be found by interpolation, and several metal spectra tested for series.

I wish to express my gratitude to Professor Kayser, of Bonn, in whose laboratory the experiments were carried out, for his valuable advice, for the invariable interest which he took in the work, and for the loan of the costly apparatus which he placed at my disposal.

Most especially are my thanks due to Herr Hans Hauswaldt for the use of his unique spectrograph and fluorspar-grating, without which it would have been impossible to carry out the research.

Mau

Manchester Memoirs, Vol. xlix. (1905), *No.* 4.

IV. On the Rigidity of Gelatine.

By H. MORRIS-AIREY, M.Sc.

Received and read January 24th, 1905.

The material used in the following experiments is a jelly made by dissolving gelatine* in warm water. On cooling, the mass becomes an elastic solid which has some interesting properties.

For all ordinary pressures (*i.e.*, up to 5 or 6 atmospheres) the material shows no diminution in volume but it is very easily distorted by tangential stress. This latter property has been made use of in optics by Clerk-Maxwell to exhibit the action of crystalline media on polarised light.

If such a jelly is saturated with a salt solution many of its physical properties, such as velocity of electrolytic ions in it, are approximately the same as those of the aqueous solution of the salt. Consequently jellies of this kind have found application in experiments where convection currents within the salt solution were to be avoided.

An interesting property is mentioned by Mactear.† A crystal embedded in a salt solution jelly, continues to grow as a single crystal developing into a very symmetrical specimen, while in an ordinary aqueous solution this is hindered by the formation of other lesser crystals. He attributes the formation of the very perfect selenite crystals found in plastic clay to this cause.

It was in connection with the use of jelly plugs in diffusion experiments that the method of measuring the rigidity of gelatine solutions was suggested.

* That known commercially as "Nelson" leaf gelatine was used.

† *Transactions of Inst. Mining and Metallurgy*, XII., 1902, p. 132.

February 16th, 1905.

Dr. Albert Griffiths,* in his experiments on the rate of diffusion of salts in water, uses plugs of jelly to prevent convection currents. Occasionally the plugs are subjected to small differences of pressure, and are distorted to an extent which depends, among other things, on the rigidity of the jelly. On obtaining an approximate formula for the distortion, it was seen that the behaviour of a cylindrical plug of jelly affords a convenient means of determining the coefficient of rigidity.

In *Fig.* 1, ABCD represents a circular cylinder of jelly contained in a tube EF with rigid walls.

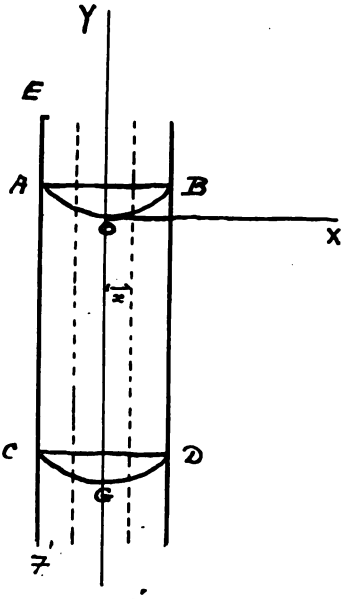

Fig. 1.

On applying a downward pressure to the upper surface of the plug, it takes the form AOB, DGC; and as the jelly may be considered incompressible, the assumption may be made that the lower surface CGD has exactly

* *Phil. Mag.* XLVII., 1899, p. 530.

the same shape as the upper surface AOB. Through O, the centre of AOB, draw two lines, OY, OX, the former coinciding with the axis of the cylinder and the latter being at right angles to it.

Let p = pressure per unit area on the surface AB.

l = length of cylinder.

R = radius of cylinder.

η = coefficient of rigidity of the jelly.

Considering the equilibrium of a mass contained within a cylinder of radius x, we obtain for the differential equation of the section of the surface AOB,

$$2\pi x\eta l\frac{dy}{dx} = p \times \pi x^2$$

whence

$$y = \frac{p}{4\eta l}x^2.$$

The surface AOB is thus a paraboloid of revolution and it can easily be shown algebraically that the volume between AB and AOB equals $\frac{\pi p R^4}{8\eta l}$. It may be incidentally mentioned that the result is analogous to the flow of a viscous fluid along a tube of circular bore.

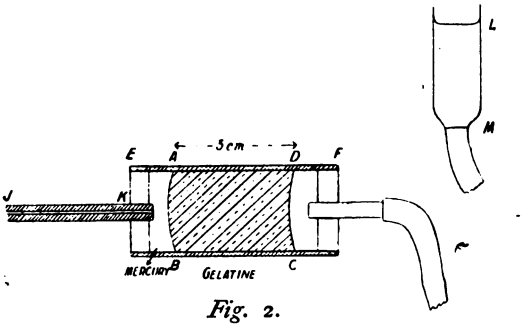

Fig. 2.

The apparatus used in the actual experiments is shown diagrammatically in *Fig.* 2.

The glass tube EF is closed at its extremities with

stout indiarubber stoppers. Through one, a capillary tube JK is fixed whilst through the other passes a tube whose extremity is attached by flexible tubing to a glass cylinder LM containing some liquid. By varying the height of LM the pressure acting on the right hand side of the jelly may be varied. The distortion of the jelly is measured by the motion of the capillary column in JK.* In filling the apparatus, the tube EF is placed in a vertical position partially immersed in mercury and the solution of gelatine is poured on to the surface of the mercury up to the required level. *Fig.* 3.

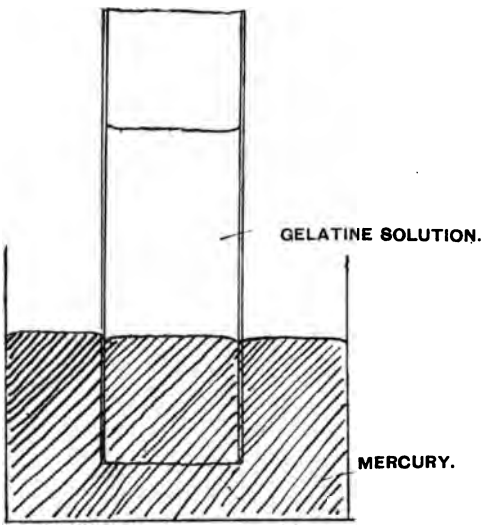

Fig. 3.

After the jelly has set the lower end of the tube is closed and the tube lifted out cautiously. Pressing the stopper containing the capillary tube into the lower end of

* Experiments were also made in which the pressure was communicated through the capillary tube, the amount by which the mercury column was forced back being measured. This was not found so convenient as the method described above.

EF, some of the mercury is forced along the capillary tube. The cavity at the other end is then filled with water in the case of pure gelatine and with salt solution in the case of jellies containing salts. The latter prevents any diffusion of the salt out of the jelly, which would occur if pure water was placed in contact with it.

The reading of the end of the capillary column is then noted and the height of the vessel LM varied.

Let h = variation in height of LM.

v = volume traversed by the jelly.

ρ = density of liquid in LM.

m = distance through which end of capillary column moves.

r = radius of capillary tube.

η = coefficient of rigidity.

It is easily seen that

$$\eta = \frac{R^4 g \rho h}{8 l r^2} \times \frac{1}{m}.$$

Before applying the formula, experiments were made with the object of testing its accuracy.

Simple experiments with a single tube proved that for a jelly which has been set for a few hours, m varies directly as h. Portions of the jelly column were then removed so as to diminish l, and the movements of a capillary column for a constant variation of h were noted.

The results were

Length of Cylinder (l).	Movement of Capillary (m).	Product ($m \times l$).
13·3 cm.	0·30 c.m.	3·99
9·7 ,,	0·41 ,,	3·97
6·4 ,,	0·63 ,,	4·03

Within the limits of experimental error $m \times l$ is a constant. Cylinders of equal length but different diameters were then filled with jelly of the same composition and arranged so that either could be connected by a system of taps with the capillary tube and the vessel LM.

According to the formula, $\frac{R^4 h}{m}$ should be constant, and this was verified to within 1 per cent.

Using pure gelatine solution containing 5 per cent. by weight of leaf gelatine, the coefficient of rigidity was determined at intervals beginning two hours after the jelly had been placed in the tube. *Fig.* 4 shows the alteration

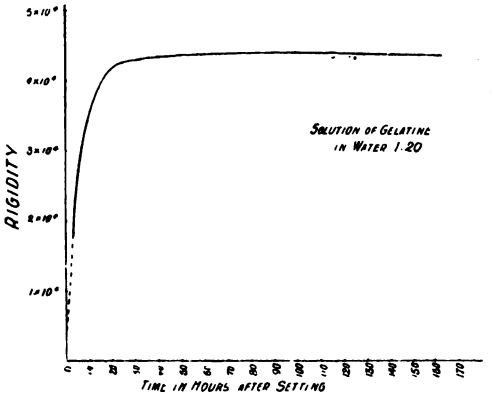

Fig. 4.

of η with the time. After attaining a steady state, which occurred about eight days after the solution had been poured into the experimental tube, the value of the coefficient of rigidity was found to be $4{\cdot}64 \times 10^4$ C.G.S. units, the lowest rigidity actually measured being $1{\cdot}68 \times 10^4$.

The most interesting portion of the curve is the ascending branch, with the shoulder joining it to the already familiar horizontal portion. I believe the apparatus described above is the only one yet devised which is

adapted to the measurements of such small values of η as occur at this stage of the solidification process.*

Observations made within an hour of filling the tube showed that the jelly behaved like a very viscous fluid, the whole mass flowing through the tube when subjected to pressure. To prevent the plug from slipping as a whole, the walls of the tube were roughened by etching a number of shallow rings by means of hydrofluoric acid on the inside surface. After two hours, the jelly shows very little viscosity, but possesses hysteresis to a great extent; that is, after removing the pressure causing a constant deformation, the plug did not return to its original position, but showed a permanent strain. This hysteresis effect became less marked as the solidification went on, until at about 20 hours after preparation it suddenly disappeared, and the further alteration in the rigidity was very slow, often being quite inappreciable in the remaining observations extending over several days. This behaviour seems to confirm the theory that solidification of matter begins round a number of nuclei. In the state represented by the ascending branch we should then have a number of globules of jelly in a more advanced stage of solidification than the material surrounding them. On subjection to pressure the more condensed masses would be elastically deformed, and would at the same time slide over one another, shearing the material between them, which would unite again when the steady state of deformation was attained. On removing the pressure the elastically deformed portions would return slightly towards their initial position, but the mass as a whole would have a permanent strain. The behaviour of the weaker portions under stress is illustrated by the fact that

* Measurements with very stiff jellies have been made by Maurer, *Wied. Ann.* **28**, 1886, p. 628, Fraas, *Wied. Ann.* 53, 1894, p. 1074.

when a feeble jelly is beaten with a glass rod it becomes fluid, uniting again into a solid on standing, the whole operation being carried out without any perceptible temperature changes.

When the globules have grown so much that neighbouring ones come into contact and grow together, the character of the deformation under pressure will now be a purely elastic one, and we should expect the sudden disappearance of the hysteresis and the sharp shoulder to the curve, which experiment actually establishes.

In view of the well-known phenomenon of condensation of water vapour round ions as nuclei, experiments were made to determine, if possible, the nature of the nuclei in the process of solidification. It has long been known that the addition of salts to gelatine solutions modifies their rigidity, and accordingly various simple salts were mixed with a gelatine solution of strength 1 in 20 and the progress of the solidification observed; the results are shown in *Fig.* 5.

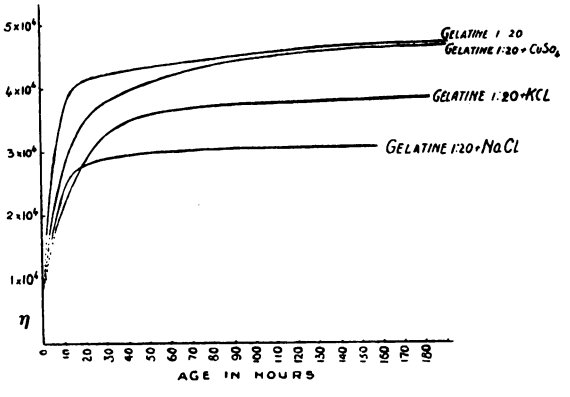

Fig. 5.

The uppermost curve is that obtained with pure gelatine. The next curve shows the effect of adding

copper sulphate. (Amount used is one fifth of the weight of water in the gelatine solution.)

The junction of the ascending and horizontal branches is not nearly so abrupt as in the case of pure gelatine, while the final value of the rigidity is slightly less than that of the pure medium. The same holds for the addition of potassium chloride and sodium chloride which were used in amounts calculated to give the same total number of gram-molecules per cubic centimetre as in the copper sulphate solution. The final values of the rigidity in these cases are in the order of the weights of salts added, which was also the order of the molecular weights of the salts. There is not sufficient material here to speculate on the actual manner in which the salts affect the properties of the jelly, but the smoothing of the curve is consistent with the presence of a greater number of nuclei, in which case the presumption would be that the electrolytic ions of the salts act as nuclei.

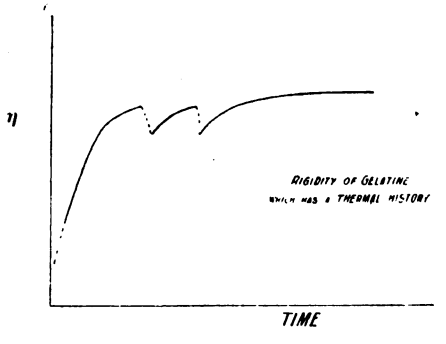

Fig. 6.

This view is supported by the fact that substances like sugar whose solutions are not accompanied by ions, do not affect the rigidity of jellies with which they are mixed.

In carrying out these measurements great difficulty

was experienced at first through temperature changes of the laboratory which produced irregularities in the curves. Finally, an underground room whose temperature was very constant, frequently varying not more than $\frac{1}{8}^{\circ}$ centigrade in several days was placed at my disposal through the kindness of Dr. Hoyle, and no further difficulty was experienced in obtaining consistent results.

The effect of two sudden rises in temperature on successive days is shown by the shape of the curve in *Fig.* 6.

The development of the last part of the curve is exactly similar to that of curves which had not been interrupted so that the previous thermal history of the material appears to be without effect.

I wish to thank Dr. Albert Griffiths, of the Birkbeck College, London, for his valuable suggestions and assistance during the above experiments.

Manchester Memoirs, Vol. xlix. (1905), *No.* 5.

V. Report on the Recent Foraminifera from the Coast of the Island of Delos (Grecian Archipelago). Part II.

By HENRY SIDEBOTTOM.

Received and read December 13th, 1904.

ARENACEA.

ASTRORHIZIDÆ.

SACCAMMININÆ.

Psammosphæra, Schulze.

Psammosphæra fusca, F. E. Schulze (Pl. 1, fig. 1).

Psammosphæra fusca (Schulze), Brady ('84), p. 249, pl. 18, figs. 1-8.

P. fusca (Schulze), Goës ('94), p. 14, pl. 3, fig. 19.

A single specimen, apparently of this species, occurs; the test is composed of small sand grains roughly cemented together. Very rare.

Crithionina, Goës.

Crithionina, sp. (Pl. 1, fig. 2).

One specimen only was found, and it is doubtful under which species it should be placed.

The test is thin, has a granular appearance, and is of a light grey-brown colour. There is a single sponge spicule embedded in the test. The jagged orifice as shown in the drawing may only be a fracture. Very rare.

February 17th, 1905.

RHABDAMMININÆ.

Jaculella. H. B. Brady.

Jaculella obtusa, Brady.

Jaculella obtusa, Brady ('84), p. 256. pl. 22, figs. 19-22.

J. obtusa (Brady), Goës ('94), p. 20, pl. 4, figs. 87-89, and pl. 5, figs. 90-91.

Unfortunately in the two specimens obtained from this locality the commencement of the test is broken off, but judging by the contour of the whole tube, I have little doubt that they belong to this species, especially as one of the tests shows signs of broadening out at the initial end, as if the small bulbous chamber, characteristic of this species, had been broken off. They measure in length about one-third of an inch, and are of a rich brown colour. Very rare.

LITUOLIDÆ.

LITUOLINÆ.

Reophax, Montfort.

Reophax difflugiformis, Brady.

Reophax difflugiformis, Brady ('79), p. 51, pl. 4, fig. 3.

R. difflugiformis, Brady ('84), p. 289, pl. 30, figs. 1-5.

R. difflugiformis (Brady), Goës ('94), p. 26, pl. 6, figs. 196-198.

Considering the size of the test, the sand grains used for its construction are large and are roughly put together. Very rare.

***Reophax scottii,** Chaster.

Reophax scottii, Chaster ('92), p. 57, pl. 1, fig. 1.

R. scottii (Chaster), Millett ('99), p. 255, pl. 4, fig. 13.

* The asterisk denotes that this species occurs at Palermo.

Fragments only of this interesting foraminifer were found; in two of them the chambers are cylindrical and not compressed as in the type. Fine examples occur at Palermo. Very rare.

Reophax arctica, Brady. (Pl. 1, figs. 3, 4).

Reophax arctica, Brady ('81), p. 405, pl. 21, fig. 2.

This is an exceedingly delicate form and is an isomorph of *Lingulina.* Six were found, all of them being more or less broken. They are transparent, the minute pieces of flat, glass-like looking substance which form the test, being of irregular shape and very neatly cemented together. In the above reference Brady does not speak of this species as being transparent, but "as a sandy isomorph of *Lingulina*," "walls arenaceous, very thin." His specimens came from the Novaya-Zemlya Sea. Very rare.

Reophax sp.? (Pl. 1, fig. 5).

Owing to the commencement of this solitary specimen having been broken off, it is impossible to be certain of its identification. The test is slightly compressed, pale cream-coloured, and almost smooth in its texture. Very rare.

Haplophragmium, Reuss.

***Haplophragmium pseudospirale,** Williamson, sp.

Proteonina pseudospiralis (Williamson), ('58), p. 2, pl. 1, figs. 2, 3.

Haplophragmium pseudospirale (Williamson), Balkwill and Wright ('85), p. 330, pl. 13, figs. 6-8.

H. pseudospirale (Williamson), Brady ('84), p. 302, pl. 33, figs. 1-4.

With few exceptions the Delos examples of this

species are much broken, but in those which have the lineal portion of the test in fair condition, the segmentation is very obscure, as in the type. They resemble very closely the specimens I have from the East coast of Ireland, off Dublin. The Palermo examples are very fine, but of a different character. Rare.

***Haplophragmium canariense,** d'Orbigny, sp.

Haplophragmium canariense (d'Orb.), Brady ('84), p. 310, pl. 35, figs. 1-5.

H. canariense (d'Orb.), Goës ('94), p. 20, pl. 5, figs. 95-101.

Small but characteristic specimens of this well-known species occur. Rather rare.

***Haplophragmium globigeriniforme,** Parker and Jones, sp. (Pl. 1, fig. 6).

Lituola nautiloidea, var. *globigeriniformis*, Parker and Jones ('65), p. 407, pl. 15, figs. 46, 47, and pl. 17, figs. 96-98.

Haplophragmium globigeriniforme (P. and J.), Brady ('84), p. 312, pl. 35, figs. 10, 11.

H. globigeriniforme (P. and J.), Goës ('94), p. 22, pl. 5, figs. 128-133.

Some of the Delos examples of this form show a strong tendency to growth in the direction of *H. anceps*, the length of the tests being greater than their width, as shown in the one I have figured. Rare.

Placopsilina, d'Orbigny.

Placopsilina cenomana, d'Orbigny. (Pl. 1, fig. 7.)

Placopsilina cenomana (d'Orb.), Reuss ('54), p. 71. pl. 28, figs. 4, 5.

Lituola (Placopsilina) cenomana (d'Orb.), Carpenter, Parker and Jones ('62), p. 143. pl. 11, figs. 11-14.

Placopsilina cenomana (d'Orb.), Brady ('84), p. 315, pl. 36, figs. 1-3.

One fine specimen found. It is coiled round a small stone, and is roughly built up of minute white sand grains. Very rare.

TROCHAMMININÆ.

Ammodiscus, Reuss.

***Ammodiscus incertus,** d'Orbigny, sp.

Operculina incerta, d'Orbigny ('39), p. 49, pl. 6, figs. 16, 17.

Ammodiscus incertus (d'Orb.), Brady ('84), p. 330, pl. 38, figs. 1-3.

A. incertus (d'Orb.), Goës ('94), p. 31, pl. 6, figs. 238, 239.

Only three found, and they are white in colour and small. Very rare.

Trochammina, Parker and Jones.

Trochammina squamata, Parker and Jones.

**Trochammina squamata* (P. and J.) Parker and Jones ('65), p. 407, pl. 15, fig. 30.

T. squamata (P. and J.), Egger ('93), p. 264, pl. 5, figs. 4-6.

T. squamata (P. and J.), Brady ('84), p. 337, pl. 41, fig. 3.

The specimens are very small, but characteristic. Frequent.

***Trochammina ochracea,** Williamson, sp. (Pl. 1, fig. 8).

Rotalina ochracea, Williamson ('58), p. 55, pl. 4, fig. 112, and pl. 5, fig. 113.

Trochammina squamata (P. and J.), Parker and Jones ('65), p. 407, pl. 15, fig. 31.

T. ochracea (Williamson). Balkwill and Millett ('84), p. 25, pl. 1, fig. 7.

This form has not, so far as I am aware, been reported from the Mediterranean, Mr. Millett in his Malay Report ('99), p. 363, says, "Hitherto it has been recorded only from the British Isles, from the Arctic Regions (Parker and Jones), and from the Channel Islands (Halkyard)." The specimens were submitted to Mr. Millett for inspection. In one case two of the tests have paired with their flat faces together, as is often the case with some of the small Discorbina. Rare.

Trochammina inflata, Montagu, sp. (Pl. 1, fig. 9.)

Trochammina inflata (Montagu), Carpenter, Parker, and Jones ('62), p. 141, pl. 11, fig. 5.

T. inflata (Montagu), Balkwill and Wright ('85), p. 331, pl. 13, figs. 11, 12.

T. inflata (Montagu), Brady ('84), p. 338, pl. 41, fig. 4.

Good, but small, examples occur, the central chambers being darker in colour than the rest, as is usual in this species. Very rare.

***Carterina spiculotesta,** Carter, sp. (Pl. 1, fig. 10).

Rotalia spiculotesta, Carter ('77), p. 470, pl. 16, figs. 1-3.

Carterina spiculotesta (Carter), Brady ('84), p. 346, pl. 41, figs. 7-10.

The tests are small, and they are dark coloured, except in one or two cases where the last chamber becomes whitish.

I have a very beautiful specimen which I found in material from the bay of Naples, in which the last four

chambers contrast most effectively with the dark centre. The fusiform spicules are fastened together with white glistening cement, which is slightly raised. It occurs more frequently at Palermo. Very rare.

TEXTULARIDÆ.

TEXTULARINÆ.

Textularia, Defrance.

***Textularia concava,** Karrer, sp. (Pl. 1, fig. 11.)

Plecanium concavum, Karrer ('68), p. 129, pl. 1, fig. 3.

Textularia concava (Karrer), Brady ('84), p. 360, pl. 42, figs. 13, 14, and pl. 43, fig. 11.

The specimens are built up of fine sand grains, and are of a pale buff colour. They vary as to the squareness of the edges, but all have the lipped orifice. Rare.

***Textularia agglutinans,** d'Orbigny.

Textularia agglutinans, d'Orbigny ('39), p. 144, pl. 1, figs. 17, 18, 32-34.

T. agglutinans (d'Orb.), Goës ('94), p. 35, pl. 7, figs. 281-284, 294-296.

The specimens vary greatly, and only a few can be considered typical. Many of them at the commencement have the chambers more or less flattened, and their edges acute, while the oral end is slightly compressed, whereas in others *(Pl. 2, fig. 1) the test approaches d'Orbigny's figures of *T. candeiana* ('39), pl. 1, figs. 25-27. Very frequent.

***Textularia gramen,** d'Orbigny.

Textularia gramen, d'Orbigny ('46), p. 248, pl. 15, figs. 4-6.

T. gramen (d'Orb.), Balkwill and Wright ('85), p. 332, pl. 13, figs. 13, 14.

T. gramen (d'Orb.), Egger ('93), p. 272, pl. 6, figs. 24-26.

The examples found are broader in proportion to their height than the one figured by d'Orbigny, and the chambers are narrower. Rare.

***Textularia rhomboidalis,** Millett. (Pl. 2, fig. 2).

Textularia rhomboidalis, Millett ('99), p. 559, pl. 7, fig. 4.

In the above reference, Mr. Millett's description runs as follows, " Test cuneiform, quadrilateral; the peripheral oblique to the lateral faces, making the transverse section of the test rhomboidal; sides slightly concave, margins rounded and lobulate, sutures curved and deeply excavated. Aperture an arched slit. Shell-substance hyaline and coarsely perforate. Length, 0·34 mm." It will be noticed that my figures of this species differ considerably from those by Mr. Millett, who informs me that his drawings were made from a particularly fine specimen, and that mine agree with the bulk of the Malay forms. Frequent.

There is a weak form of the above species present in considerable numbers *(Pl. 2, fig. 3) which, on the one hand, appears to run into *T. rhomboidalis*, Millett, and on the other to broaden and flatten out towards *Bolivina difformis*, Williamson, sp., (*B. pygmæa*, Williamson), Brady ('84), p 421, pl. 53, figs. 5-6).

This variety seems also related to the British form of *B. plicata*, d'Orbigny, which, by the way, does not agree with d'Orbigny's figure. Very frequent.

Spiroplecta, Ehrenberg.

Spiroplecta sagittula, Defrance, sp. (Pl. 2, fig. 4.)

Textularia sagittula (Defrance), Brady (**'84**), p. 361, pl. 42, fig. 17.

Spiroplecta sagittula (Defrance), Wright (**:02**), p. 211, pl. 3, figs. A, B, C, D, E.

Spiroplecta wrighti, Silvestri (**:03**), p. 59.

Spiroplecta sagittula, Defrance, sp.
Longitudinal section of the test. × 50.

There is no doubt, as the sections prove, that this Delos form is a true *Spiroplecta*; whether it is identical with *Textularia sagittula*, Defrance, seems at present a matter of opinion.

The subject is discussed by Messrs. Wright and Silvestri in the above references. Only four have been found, and they are apparently all in the megalospheric condition. Very rare.

Verneuilina, d'Orbigny.

***Verneuilina polystropha,** Reuss, sp.

Verneuilina polystropha (Reuss), Goës ('94), p. 32, pl. 7, figs. 247-255.

V. polystropha (Reuss), Brady ('84), p. 386, pl. 47, figs. 15-17.

Very good examples of this species occur. In all cases the test is white, rough and glistening. Those from Palermo are, as a rule, of a rusty red hue and very large. Frequent.

***Verneuilina spinulosa,** Reuss. (Pl. 2, fig. 5).

Verneuilina spinulosa, Reuss ('50), p. 374, pl. 47, fig. 12.

V. spinulosa (Reuss), Brady ('84), p. 384, pl. 47, figs. 1-3.

In the long examples there is a decided twist in the contour of the shell, as shown in the one figured. The test is a good deal roughened, and only becomes clear in the last few chambers. Frequent.

BULIMININÆ.

Bulimina, d'Orbigny.

***Bulimina subteres,** Brady.

Bulimina presli, var. *elegantissima* (d'Orb.), Parker and Jones ('65), p. 374, pl. 15, figs. 12-17.

B. subteres, Brady ('84), p. 403, pl. 50, figs. 17, 18.

B. subteres (Brady), Goës ('94), p. 46, pl. 9, figs. 445-453.

The tests of the specimens obtained are very transparent and vary a good deal in size. Frequent.

***Bulimina elegantissima,** d'Orbigny. (Pl. 2, fig. 6.)

Bulimina elegantissima, d'Orbigny ('39), p. 51, pl. 7, figs. 13, 14.

B. elegantissima (d'Orb.), Williamson ('58), p. 64, pl. 5. figs. 134, 135.

B. elegantissima (d'Orb.), Millett (:00), p. 276, pl. 2, fig. 4.

The length of the upright chambers in the last whorl of this form varies considerably. In some cases this whorl crosses the back of the test half-way up, while in others it crosses close to the bottom. Frequent.

***Bulimina elegantissima,** d'Orbigny, var. (Pl. 2, figs. 7-12, and Pl. 3, figs. 1, 2.)

This variety is chiefly remarkable for the great number of paired tests that occur. I have about 50 picked out, and they show every stage of growth, viz., from a single chamber up to the adult stage. In the large majority of cases one of the pair is in the adult stage, and the other in one of the stages as shown in the figures. The initial chamber of this variety varies so much that it would be interesting to find out if the forms that pair are in the microspheric and megalospheric condition. As very accurate measurements would have to be taken, entailing a good deal of extra work, this problem must stand over for the present. There is a fine ring of what looks like brown cement encircling the tests, just at their juncture. Mr. J. J. Lister (:03, p. 126) illustrates by photography one of these pairs which I sent to him, and states by way of explanation that the process called "Plastogamy" probably accounts for the phenomenon. It seems strange that a test consisting of only one or two chambers, and therefore in an apparently very immature

state, should be able to perform its share of the process. It is to be noted that some of the single specimens have the mouth destroyed, in all cases leaving a comparatively large circular orifice (Pl. 3, fig. 1). These probably are individuals that have paired, and become separated, either after the process of " Plastogamy " has been completed, or during the washing of the material. One test has a " balloon " chamber entirely covering its mouth, as shown in Pl. 3, fig. 2. This " balloon " is quite transparent, and the orifice of the test can be clearly seen through it. Very frequent.

***Bulimina aculeata,** d'Orbigny.

Bulimina patagonica, d'Orbigny ('**39**), p. 50, pl. 1, figs. 8, 9.

Bulimina pupoides, var. *spinulosa*, Williamson ('**58**), p. 62, pl. 5, fig. 128.

B. aculeata (d'Orb.), Brady ('**84**), p. 406, pl. 51, figs. 7-9.

The Delos forms of this species agree best with *B. patagonica* in the above reference, except that the test is straight and not curved. Some of them approach **B. echinata*, d'Orbigny, as figured by Fornasini (**:01**), pl. 0, fig. 38. Rare.

***Bulimina convoluta,** var. **nitida,** Millett. (Pl. 3, fig. 3.)

Bulimina convoluta, var. *nitida*, Millett (**:00**), p. 280, pl. 2, fig. 10.

Mr. Millett in the above reference states: " This variety is almost purely Rotaliform, the secondary series of chambers being very small, and often scarcely discernible. The aperture, like that of the type, is situated at the superior junction of the last added primary and secondary chambers, and is usually a straight horizontal

slit as figured. The shell substance is opaque and lustrous, almost iridescent." In the Delos examples of this variety the aperture consists "of a small funnel-shaped depression," as Mr. Millett states is sometimes the case in the Malay specimens. The tests are partly lustrous and partly transparent. Rare.

Virgulina, d'Orbigny.

***Virgulina schreibersiana,** Czjzek. (Pl. 3, fig. 4.)

Virgulina schreibersiana (Cz.), Egger ('**93**), p. 290, pl. 8, figs. 93, 95.

V. schreibersiana (Cz.), Brady ('**84**), p. 414, pl. 52, figs. 1-3.

***Virgulina squamosa,** d'Orbigny. (Pl. 3, fig. 5.)

Virgulina squamosa (d'Orb.), Goës ('**94**), p. 47, pl. 9, figs. 454, 456, 460.

Virgulina squamosa (d'Orb.), Parker, Jones, and Brady ('**65**), p. 29, pl. 2, fig. 66.

***Virgulina subsquamosa,** Egger.

Virgulina subsquamosa (Egger), Brady ('**84**), p. 415, pl. 52, figs. 7-11.

All the Delos examples of these three forms run into each other, and show no line of demarcation. Some of them agree very well with Brady's figures ('**84**), pl. 52, figs. 1-3, of *V. schreibersiana*, while the one figured is a shorter and stouter variety. These latter merge through *V. subsquamosa* into the flat textularian form of *V. squamosa* (Pl. 3, fig. 5). The intermediate forms are very frequent, the others rare.

Bolivina, d'Orbigny.

***Bolivina punctata,** d'Orbigny.

Bolivina punctata, d'Orbigny ('39), p. 63, pl. 8, figs. 10-12.

B. punctata (d'Orb.), Brady ('84), p. 417, pl. 52, figs. 18, 19.

B. punctata (d'Orb.), Goës ('94), p. 49, pl. 9, figs. 475-480.

B. punctata (d'Orb.), Flint ('99), p. 292, pl. 38, fig. 1.

In a few of the tests the puncta show a tendency to form in lines, coalesce, and cause the surface in places to become delicately striate, but not to such an extent as to warrant any of them being placed under *B. nobilis*, Hanken. Common.

***Bolivina textilarioides,** Reuss.

Textularia variabilis, var. *lævigata*, Williamson ('58), p. 77, pl. 6, fig. 168.

Bolivina textilarioides, Reuss ('62), p. 81, pl. 10, fig. 1.

B. textilarioides (Reuss), Brady ('84), p. 419, pl. 52, figs. 23-25.

Two forms are present, one with compressed chambers, and the other with chambers more or less inflated and more numerous. Respectively rare and frequent.

***Bolivina tortuosa,** Brady. (Pl. 3, fig. 6).

Bolivina tortuosa, Brady ('84), p. 420, pl. 52, figs. 31-34.

B. tortuosa (Brady), Egger ('93), p. 298, pl. 8, figs. 43, 44.

About twenty have been found, and they are typical. Rare.

***Bolivina limbata,** Brady.

Bolivina limbata, Brady ('84), p. 419, pl. 52, figs. 26-28.

B. limbata, Egger ('93), p. 300, pl. 8, figs. 10-12.

The specimens agree fairly well with the "Challenger" figures in the above reference. In two of the specimens the change from the biserial to the uniserial growth has taken place, two uniserial chambers being added. Rare.

A variety which occurs with greater frequency, and comes nearest to this form, is broader than the type and the parallelism of the sides is lost. In the large specimens the tests are not so transparent, and have a milky-blue appearance. The tendency of variation, especially in the smaller examples, is towards *B. nitida*, Brady. Frequent.

Bolivina robusta, Brady, var. **compacta,** nov. (Pl. 3, fig. 7).

The test is not so broad as *B. robusta* Brady ('84), pl. 53, fig. 7, and the sides are rounded, and in transverse section the shell is more regularly oval. It is never armed with a spine at the aboral end as is often the case with *B. robusta*. The test is rather coarsely perforated, and in most cases the raised edges of the puncta coalesce, forming a beautiful areolation which gives to the shell a silvery look. Rather rare.

Bolivina difformis, Williamson, sp.

Textularia variabilis, var. *difformis*, Williamson ('58), p. 77, pl. 6, figs. 166, 167.

Bolivina pygmæa, Brady ('84), p. 421, pl. 53, figs. 5, 6.

There is only a single and doubtful example that can be brought under this species, and it is nothing more than one of the *weak forms* referred to under *Textularia rhomboidalis*, Millett, which has broadened out and

become flat, with the irregular ends of the chambers slightly pointed. Very rare.

Bolivina costata, d'Orbigny. (Pl. 3, fig. 8).

Bolivina costata, d'Orbigny ('39), p. 62, pl. 8, figs. 8, 9.

B. costata (d'Orb.), Brady ('84), p. 426, pl. 53, figs. 26, 27.

The one example found is more like Brady's figure in the above reference, than d'Orbigny's unsatisfactory illustration. Very rare.

Mimosina, Millett.

***Mimosina hystrix,** Millett, var. (Pl. 3, fig. 9).

Mimosina hystrix, Millett (:00), p. 549, pl. 4, fig. 14.

I am indebted to Mr. Millett for his suggestion that these specimens belong to the genus *Mimosina*. Such, upon examination, proved to be the case, as indicated by the texture of the shell-wall, and by the two apertures. They are not typical of any of the forms as figured by him in his Malay work, but come nearest to *Mimosina hystrix*. They are triserial at the commencement, and subsequently biserial, but the orifices differ as shown in the one figured. The spines likewise are not so well developed, and the tests are very often much more club-headed than the one I have figured, which is caused by the sudden inflation of the last two chambers.

The triserial arrangement of the chambers at the commencement is often difficult to trace. Frequent.

CASSIDULININÆ.

Cassidulina, d'Orbigny.

***Cassidulina lævigata,** d'Orbigny.

Cassidulina lævigata (d'Orb.), Williamson ('58), p. 68, pl. 6, figs. 141, 142.

C. lævigata (d'Orb.), Brady ('84), p. 428, pl. 54, figs. 1-3.

C. lævigata (d'Orb.), Goës ('94), p. 43, pl. 8, figs. 418, 420.

Small specimens occur, but they are typical. The Palermo examples are very fine. Very rare.

***Cassidulina crassa,** d'Orbigny.

Cassidulina crassa, d'Orbigny ('39), p. 56, pl. 7, figs. 18-20.

C. crassa, d'Orbigny ('46), p. 213, pl. 21, figs. 42, 43.

C. crassa (d'Orb.), Brady ('84), p. 429, pl. 54, figs. 4, 5.

These are better developed than the preceding species. Frequent.

***Cassidulina bradyi,** Norman. (Pl. 3. fig. 10.)

Cassidulina bradyi (Norman), Brady ('84), p. 431, pl. 54, figs. 6-10.

C. bradyi (Norman), Goës (94), p. 44, pl. 8, figs. 423-426.

Brady states ('84), p. 431, "This species was discovered many years ago by the Rev. A. M. Norman, and in the absence of any published description has been referred to by subsequent authors under his manuscript name."

This occurs at Palermo as well as at Delos, and at both places it is very rare.

Cassidulina bradyi, Norman, var. **elongata,** nov. (Pl. 3, fig. 11.)

Test elongate, compressed, slightly curved, transparent; a row of minute pores shows along the junction of

the chambers ; orifice situated in a depression on the face of the final chamber.

This variety seems to be an extreme development of *C. bradyi*, in which both the planospiral arrangement of the earliest chambers and the obliquity of the biserial chambers is lost. In the *C. bradyi*, var. *stenostegica* (Goës) ('94), p. 44, pl. 8, fig. 427, the obliquity is very great. I have made the small pores of the test rather too apparent in my drawing. On the back of the test they are hardly discernible. Pl. 3, fig. 11*b*, shows an outline of the form viewed by direct light, and Pl. 3, fig. 11*c*, the same form viewed by transmitted light. In this latter, the orifices of the chambers show as circular openings for nearly the whole length of the test. Very rare.

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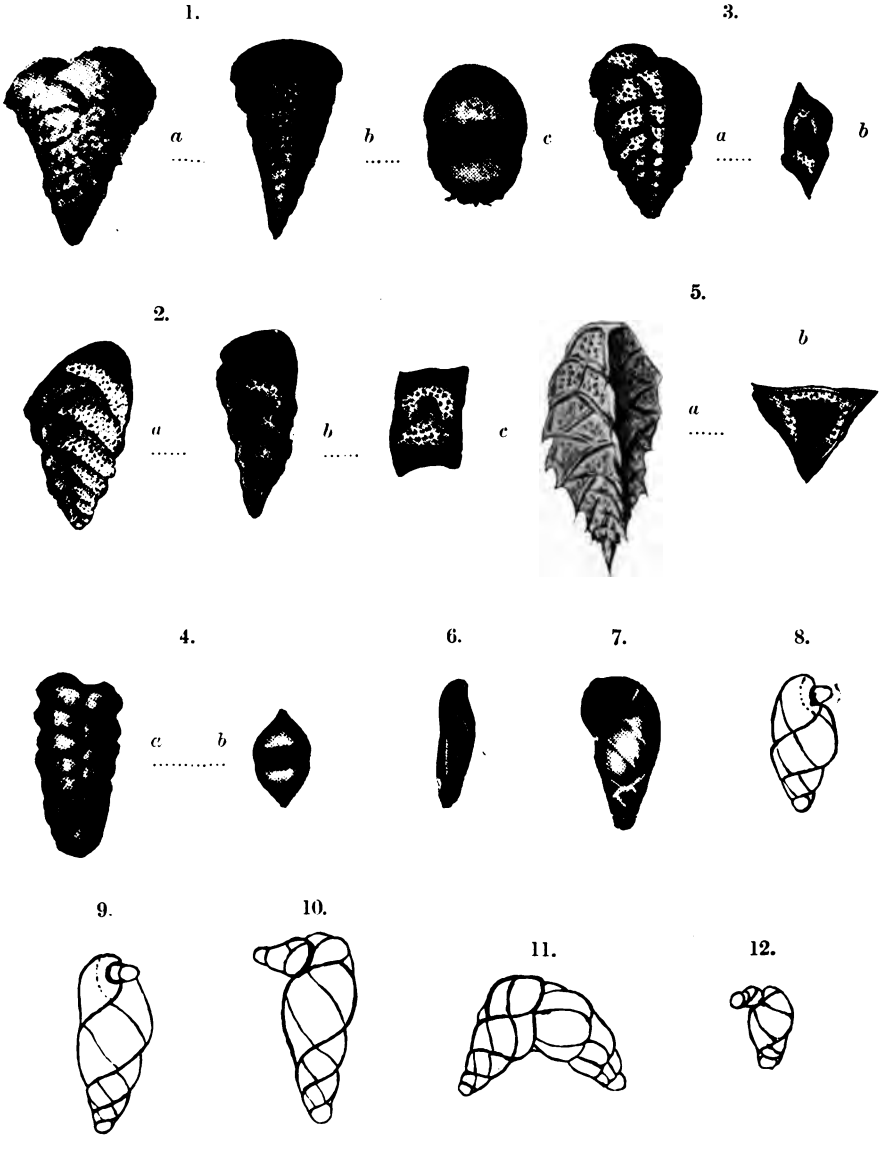
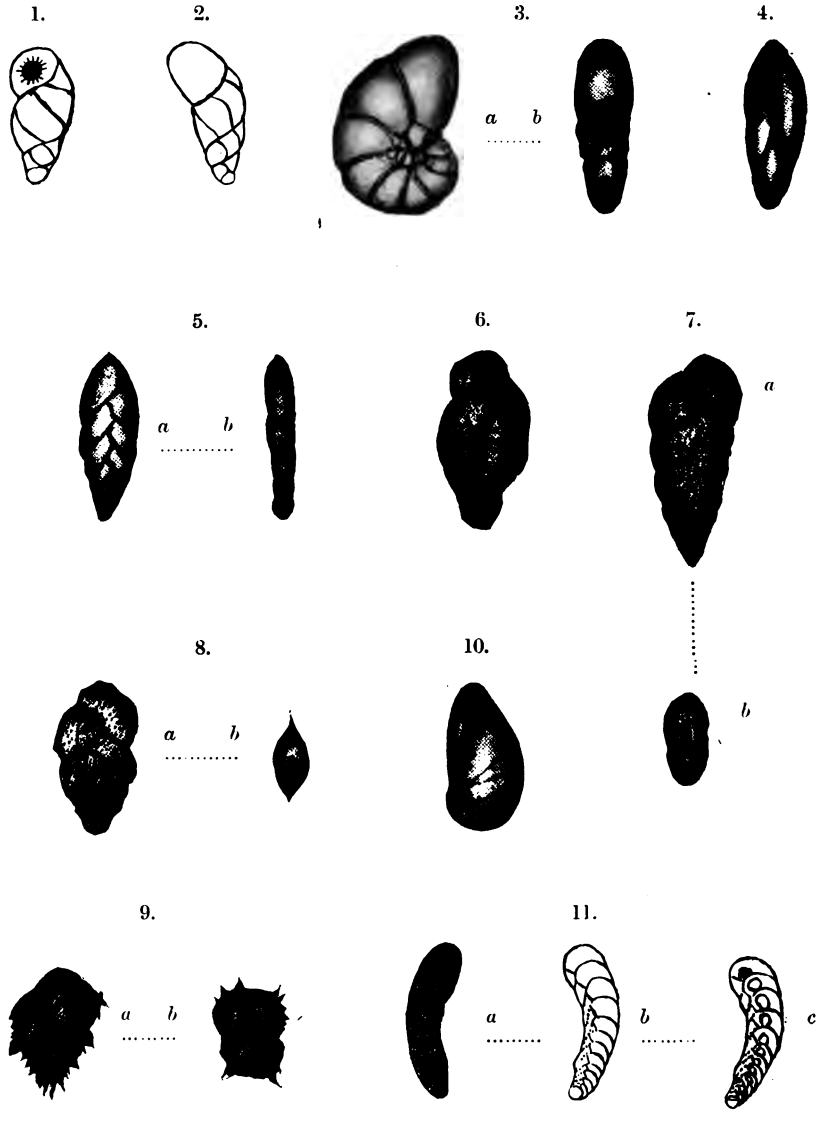


H. Sidebottom, del. ad nat.

Foraminifera from the coast of the island of Delos.



H. Sidebottom, del. ad nat.

Foraminifera from the coast of the island of Delos.

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VI. On the Supposed Antagonism of Mendelian to Biometric Theories of Heredity.

By A. D. DARBISHIRE, M.A.

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I.*

Dissensions in scientific matters may be said to be of two kinds, of which one is a disagreement about fact, and can be settled by an appeal to fact, while the other is the conflict of theoretical interpretations which cannot be so easily concluded. When Owen said that an ape's brain had not a hippocampus minor and Huxley asserted that it had, Flower announced that he had an ape's brain in his pocket: and the dissection of the brain put an end to the discussion. But in the second form of controversy no such touchstone can be applied, and in the debate on heredity at Cambridge this year Mendelian maize-cobs were displayed in vain. Of this kind of controversy there are again two sorts, one in which the theories put forward by the opposite factions are mutually exclusive, and another in which while there is apparent incompatibility the truth of both of the hypotheses is ultimately demonstrable. It remains to be seen to which of these subdivisions the Cambridge debate† and the wider discussion of which it was the outcome, are to be assigned. If the two theories are mutually exclusive, which is right? If on the other hand they are not, how do they fit in with one another? These are questions which "the general enquiring public" may be

* This essay is so arranged that if the reader is not interested in the phenomenon of hybridization he may leave out Part II.

† Reported in *Nature*, Vol. 70, pp. 538 and 539.

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expected to ask and to which the specially trained biologist may be expected to supply an answer.

It is the thesis of the present essay to demonstrate the compatibility of Mendelian and biometric theory and to account for their apparent antagonism.

A few words as to the spirit and scope of this essay seem to me to be necessary. There are two methods of scientific criticism, if indeed one of them can be justly called scientific. One arises from a determination to crush a theory, while the other consists in the postponement of the attack until every endeavour has been made to appreciate the exact point of view of the upholders of that theory, and in a willingness to put off the attack for ever if the theory should not be found wanting after all. The most flagrant example of the first kind of criticism, on which I can lay hands, flowed from the pen of a writer who, after having misrepresented the theory he was attacking by declaring that it was "an essential part of the Mendelian hypothesis that the (so-called 'extracted') recessive individual which is produced by pairing two first crosses, is in every respect similar to the original pure recessive,"* concludes with these words: "This mouse is clearly not a pure dominant, because it produces albinos; it is not a dominant hybrid because it has pink eyes; and it cannot be a recessive because when paired with an albino it produces some black-eyed forms." It is evident from this quotation that the stimulus which actuated the author was a desire to stultify and refute Mendelian theory at all costs, and that he did not make the smallest attempt to discover what Mendelian theory really was or to put himself in the position of those who held it to be true. For an example of the second form of criticism I suggest that the reader may turn to the

* A. D. Darbishire, *Biometrika*, Vol. II., pp. 282 and 285.

following pages: in them I shall do my best to discover the most essential characteristics of Mendelian and biometric theory and so to put myself in a position to discuss their mutual relationship.

With regard to the scope of this essay, there is one point I wish to emphasize: it may be that some critic will lay down this pamphlet with the remark that all that he has read may be very true, but that the fact remains that the only thing which "matters" is the mass-phenomenon; or another may declare that the key which will unlock the secret of heredity can only be obtained by a study of the properties of the germ cells. I do not propose to express an opinion on either of these contentions, but I wish most strongly to insist that when a man has made either of them, he has stepped from one country into another. After discussing the mutual relation of two theories, he suddenly asserts that after all it is only one of them that matters—as one who during a discussion of the evidence for and against the existence of mental activity after the death of the brain should declare that after all, belief in such a survival was a great comfort to many: both questions may be worth discussing, but they should be discussed separately. In this essay I propose to treat of the mutual relations of the two theories purely as theories, without touching on the question of their possible value to the pure or applied biologist.

The reader may easily convince himself by a perusal of the literature on this subject that the self-same facts are interpreted by the rival schools of thought in the light of their own theories: and if he looks for recognition from either party that there may be something of truth in the opinions of their opponents, he will search in vain. I do not propose to discuss the opposite points of view, because I believe that the remedy for the present inconclusiveness

of the discussion lies very deep, and is to be found in the clear appreciation of the fundamental relation between the biometric and Mendelian points of view.*

II.

At a time when I did not clearly see this relation, I had before me some data which convinced me that the Mendelian interpretation of the phenomenon of segregation was wrong, and that the facts were striking evidence of the truth of Galton's theory.

There are two attributes of a heterozygote which are said to follow from the theoretical constitution of its gonad; one is that a quarter of the population produced by the union of heterozygotes consists of individuals bearing the recessive character; and the other is that half the population produced by mating heterozygotes with recessives consists of recessives. My hybrids† were tested for these two properties and the results were not denied to be in accord with Mendelian expectation. But this result was not conclusive in favour of that theory only, because the proportion of recessives demanded by Mendelian theory in the case of the first property was identical, and in the case of the second only slightly less than that which follows from the truth of Galton's generalization.‡

The Galtonian prediction of the number of albinos that will be produced by two hybrids (H) each of which is the offspring of a pure-bred waltzing and a pure-bred albino mouse is ·25 of their generation; while on that theory the proportion of albinos in a generation resulting from the union of hybrids with albinos (A) is ·53125, if

* The reader who wishes to follow the discussion of the facts at first hand will find the necessary references to four cases in the Appendix.

† *Biometrika*, Vol. III., pp. 30—33.

‡ Francis Galton, *Proc. Roy. Soc.*, Vol. 61, p. 402, line 13.

we only calculate as far back as the great-grandparental generation.

We have seen, therefore, that hybrids were mated with hybrids, and that they were also mated with albinos. In this way two kinds of hybrids were produced which could not be distinguished from one another by their outward appearance but differed in the amount of their albino ancestry; for while the one kind, which we may call HH, resulted from the union of two hybrids, the other, HA, was the offspring of a hybrid and an albino. I took those individuals to be hybrids which resembled the first crosses (F_1) in coat and eye colour, *i.e.*, in the possession of a coloured coat and pigmented eye.

In mating hybrids of this generation (F_2) I did not previously look up their ancestry in books containing their genealogical record, so that mice of the categories HH and HA were mated at random: in this way three kinds of crosses were made HH × HH, HH × HA and HA × HA. In each type of union a hybrid was mated with a hybrid, as I believed at the time: and as on Mendelian theory there is no difference between the gametic constitution of DR produced by DR × DR and DR with parentage DR × RR, I argued* that, if that theory were true, each type of union would produce a fraternity, half of which would be composed of hybrids, a quarter of which would be composed of pink-eyed mice with coloured coats, while the remaining quarter would consist of albinos; on the other hand, it was evident that on Galton's theory of heredity the proportion would not only not be the same in each of the three cases but would differ in direct proportion to the amount of albino blood in the parents of the population. The subjoined table gives together with the actual result, the proportions of albinos as predicted

* *Biom.*, Vol. III., pp. 23—25.

by the two theories: in calculating the Galtonian prediction I have not taken into account any generations more remote than the great-great-grandparental.†

Type of Parentage.	Number of Young.	Mendelian Expectation.	Galtonian Expectation.	Actual Result.
HH × HH	93	25 %	9·37 %	10·75 %
HH × HA	107	25 %	17·96 %	18·69 %
HA × HA	121	25 %	26·56 %	24·79 %

Before continuing my argument, I should like to dwell for a little on the circumstances which led me to believe that I was dealing in F_2 with hybrids and indeed with heterozygotes in the strict Mendelian sense of the term. In the first place these putative hybrids bore the same features of coat and eye colour as the F_1 hybrids exhibited; secondly, they formed 50% of the F_2 generation, and lastly at least two upholders of Mendelian theory* had asserted that the heterozygote was represented in my experiment by the coloured mice with pigmented eyes.

To resume the thread: these results were brought before the notice of a student of heredity whose first question was, if there had ever resulted from the union of two hybrids a family in which there were no albinos; a query to which an affirmative answer was given. Then the following argument was used by my critic: 'The only proof that a given individual is a hybrid is one which is based on an examination of its gametic constitution; in the case of your mice you have no right to say that a grey mouse with black eyes is a hybrid until

* Castle and Allen., *Proc. Amer. Acad. Arts and Sci.*, Vol. 38; No. 21.

† I thank Mr. J. T. Wadsworth for checking this simple calculation.

you have mated it with an albino and obtained albino young in the litter thus produced: until this has been done there is no evidence that it is not a dominant. In the case you have just shewn me you mated coloured mice with dark eyes without making this test, and by this neglect many dominants may have been included among them, and you see that this suggestion, against the truth of which you have no evidence, accounts just as well as Galtonian theory for the difference in the proportions of albinos in the three kinds of matings.' I replied that the test of the true heterozygote nature of the apparent hybrids should be made though I did not believe the suggested Mendelian interpretation of this apparently conclusive anti-Mendelian result.

The test has been applied with the most remarkable result: but before giving an account of it I propose to describe my reasons for adhering to the interpretation of the facts of this case which I held at first. I believed that all the individuals in F_2 with pigmented coats and eyes were hybrids and that when mated with albinos they would all of them give some albinos; that the hybrids of F_2 differed from those of F_1 only in degree, namely that, while it was the property of the latter when mated together to produce as nearly as possible one albino in every four in their litters, the former had a less albino-producing capacity; and that the hybrids of F_3 would each be capable of producing still fewer albinos and so on with succeeding generations. My belief was that the hybrids of a given generation, say F_5, would be all the same with regard to their albino-producing capacity, but would differ from those of F_4 in having a smaller one. Before dealing with the origin and meaning of this view I will relate how, by the application of the test suggested, it was shewn to be erroneous. The test of the real

heterozygote nature of the hybrids was made, as suggested, by mating them with albinos. In all cases but two I found as I had expected that albinos were produced: and I ascribed the absence of albinos from the other two litters to chance, and had no doubt that I had only to mate them with albinos again to obtain the required proof of their hybridity. But the next litters from the two mice, mated thus, contained no albinos. So that it began to look very much as if these apparent hybrids really were dominants. This fact in itself pointed to the truth of the suggestion that mice with coloured coats and eyes were of two kinds—hybrids and dominants; but coupled with the result of mating the gametically tested hybrids *inter se* it afforded fairly complete confirmation of that hypothesis, for of the 92 young resulting from such union, 14 had a pink eye and coloured coat, 58 a dark eye with coloured coat, while 20 were albinos.

I wish particularly to remind the reader that I do not think that these numbers are large enough to draw any numerical conclusions from; they are introduced solely as part of an argument which is intended to shew how I came to see that the facts summarized in the Table on p. 6, were equally in accord with Mendelian and Galtonian theory: and their value in this respect will not be in the least impaired if it ultimately turns out that the proportion in which the three categories of coat and eye colour occur are "in every respect discordant with" Mendelian prediction.

That the two mice which gave no albinos in the two matings referred to really are dominant is, I think, placed beyond doubt by the fact that in a third mating with albinos they have failed to produce anything but coloured mice with black eyes.* That the remaining mice are

* Besides these two mice which have been tested thrice there are three which have been tested twice, two bucks and a doe, with the same result.

heterozygotes is also beyond doubt, and that a quarter of the population produced by breeding them together is composed of albinos remains to be demonstrated. The Table on p. 6 therefore is in no wise a refutation of Mendelian theory; at any rate the suggested Mendelian interpretation of the facts cannot be regarded as disproved. Nevertheless the facts are no less in accord with Galtonian theory, though in a different way than I at first held: the manner in which I believed that the truth of that theory would be borne out was as I have said before, and as I wish to emphasize again, by the gradual diminution of the albino-producing capacity of *each* hybrid of successive generations. It now appears that the manner in which that theory is borne out by these facts is by the gradual invasion of the 'hybrid' ranks in successive generations by dominant individuals bearing the external hybrid characteristics: whether there will appear among the 'dominants,' or even recessives a compensating number of hybrids, or even whether this is demanded by Mendelian theory is a question of fact which does not affect my argument. What I want to point out is that I fell into the error of believing that that which was true of the whole population was also true of the individual—a mistake which, I believe, was due to an attempt to discover whether certain phenomena were evidence in favour of the one or the other of two theories without appreciating the essential character of either theory and much less their mutual relation; to a failure, in short, to realise that a biometric formula of heredity is true only of large masses, the component units of which in most cases unite at random, while the Mendelian theory is an attempt to account for the hereditary phenomena exhibited by the union of individuals carefully selected, by a theory of the constitution of their germ

cells. It is perhaps not unnatural, though it is certainly unjustifiable, that, when an experimenter is thinking of a set of facts before him now in terms of the one theory and now in terms of the other without having clearly fixed the peculiar characters of each theory to its proper owner, he should get these characters misplaced, that he should add to the real character of the biometric theory one which it does not possess—that of applicability to the individual. I have discussed this particular error of judgment at some length because it illustrates the kind of mistake a student of heredity at the present time may make unless he realises the exact nature, at which I have so far only hinted, of the two theories whose compatibility with fact he is testing. Were I not persuaded that mine is not the only case in which this or a similar kind of error has been made I should not have described it: and it is because I believe that the misunderstandings and arguments at cross purposes, which have lately characterized discussions on heredity, will be things of the past when the relation between biometric and Mendelian theory is clearly seen that I set forth the following considerations.

III.

From a point of view which commands a wide range of our experience, our knowledge may be divided into two distinct classes, according as we are dealing collectively with a vast number of things—with a mass phenomenon; or with the individual units which make up that mass. These two kinds of knowledge are radically different, and are distinguished from one another by the same characters as those which are peculiar to the two meanings of the statement that a thing happens by chance; for when we make this statement we may either be referring to the method by which I decided whether to write 'biometric'

or 'Mendelian' first in the title of this paper, or to the result of a very great number of tosses—an approximation to 50 % heads and 50 % tails, which is close in proportion as the number of trials is great. The first difference that I mention between these two meanings of chance, as illustrative of the characters of the two classes into which we have divided our aspect of things, is that, while in the case of the first it is impossible to predict the result of a single trial, there is nothing easier to foretell than the result of a very large number; nothing is more uncertain than the former, nothing more certain than the latter. A second difference between these two groups is that that which is true of the mass is not necessarily true of all the component individuals, though it may be of some: in the case of coin-tossing, the statement that the result of an infinitely large number of trials is an equal number of heads and tails is contradicted at every single toss, though this would not be the case if some of the coins we tossed had half the head and half the tail on each side of the coin.* Is it necessary to add that from the fact that what is true of the mass is not true of the individual it does not follow that assertions about the individual are antagonistic to statements about the mass? It is important to realise this truth because it is seldom done and apparently difficult, the difficulty resulting from the extreme difference of the two points of view. A midge walking across a picture of a meadow done by the three-colour process would assert that it was traversing a white plain, over which were distributed patches of different sizes and three colours, red, blue, and yellow: a child would main-

* I have found Galton's apparatus for illustrating the origin of the curve of frequency (*Natural Inheritance*, p. 63, *Fig.* 7) very useful for explaining the difference between these two classes. An example of the first is afforded by allowing a single shot to run down the inclined board; an example of the second by displaying the result of a thousand such events.

tain that it was walking across a picture of a field ; each would be convinced that he was right and the other wrong ; yet that both were right could be recognized by any man able to use a magnifying lens. This leads us to a third feature of the relation between our two classes, (which results from the fact that our knowledge has probably developed along those lines that our point of view has made most valuable), namely, that in proportion as our knowledge of the component units is small so is our knowledge of the mass result great.

To take an example of these two ways of looking at things. The climate of a country or long period of time is a mass-phenomenon : the particular climatic condition of a certain day is referred to as the weather.* It is, though it may be becoming less, impossible to predict the weather with precision : but the nature of the climate of a given country or long period of time is a matter of tolerable certainty. Yet the statement that the summer is warm does not exclude the possibility of a frost in May. That our practical knowledge of the elements is confined to the climate is evident from the fact that, having procured, we begin to put on warmer clothing at a certain period of the year : but if our intelligence were so sharpened, or our meteorological instruments so improved that we could predict the exact state of the weather a fortnight in advance, we should not procure the warmer raiment until we knew that it would be needed.

Another phenomenon which may be looked at from these two points of view is that of the causation of heat :

* "By *climate* we mean the sum total of the meteorological phenomena that characterize the average condition of the atmosphere at any one place on the earth's surface. That which we call *weather* is only one phase in the succession of phenomena whose complete cycle, recurring with greater or less uniformity every year, constitutes the climate of any locality." P. 1.—J. Hann's "Handbook of Climatology," transl. by R. de C. Ward, 1903.

it is believed that the heat of a substance is occasioned by the mean speed at which the molecules of which it is composed are travelling. To deal with the three differences between our two aspects of things in turn; it is evident first that, while our ignorance of the speed of an individual molecule is so great that we try to conceal it by saying that it is determined by chance, our knowledge of the average speed of myriads of them is so accurate that certain laws of thermo-dynamics have been formulated. Secondly, it has been calculated that a curve representing the frequency of the various speeds spread over the molecules is an ordinary curve of error; so that although that which is true of the mass is also true of some of the molecules, it is by no means true of all of them. Thirdly, the only point of view from which we can regard this phenomenon at present is that from which we can only discern the mass-result: but that it is by no means inconceivable that there may be another point of view is evident to all who are familiar with Clerk Maxwell's demon, a being who is so essential to my argument that I shall make no apology for quoting his creator's description of him in full: "One of the best-established facts in thermo-dynamics is that it is impossible in a system enclosed in an envelope which permits neither change of volume nor passage of heat, and in which both the temperature and pressure are everywhere the same, to produce any inequality of temperature or pressure without the expenditure of work. This is the second law of thermo-dynamics, and it is undoubtedly true so long as we can deal with bodies only in mass, and have no power of *perceiving or handling the separate* *. molecules of which they are made up. But if we conceive a being whose faculties are so sharpened that he can follow evey molecule in its course, such a being,

* My italics.

whose attributes are still as essentially finite as our own, would be able to do what is at present impossible to us. For we have seen that the molecules in a vessel of air at uniform temperature are moving with velocities by no means uniform, though the mean velocity of any great number of them, arbitrarily selected, is almost exactly uniform. Now let us suppose that such a vessel is divided into two portions, A and B, by a division in which there is a small hole, and that a being who can see the individual molecules, opens and closes this hole, so as to allow only the swifter molecules to pass from A to B, and only the slower ones to pass from B to A. He will thus without expenditure of work, raise the temperature of B and lower that of A, in contradiction to the second law of thermo-dynamics."

The point of view of the demon is so different from that of the physicist that one of the truest generalizations of the latter would be declared absolutely false by the former: yet no one remains blind for a moment to the fact that the contradiction of their respective statements is only apparent, and is due to the radical difference in their points of view.

Now I believe that the difference between the point of view of the Mendelian and the biometrician is very like the difference between that of the demon and that of the physicist. The biometrician, with a new weapon of observation, is only concerned with mass phenomena; the individuals which go to swell his correlation tables are, like the atoms of the physicist, units of which no knowledge is required to attain the result at which he aims. But I need not dwell on the exactness of the parallel when we have these words from "the inventor of the term biometry*":—"†Our knowledge of atoms

* *Nature.* Oct. 27, 1904. P. 626.

† Karl Pearson. "Grammar of Science," 2nd Ed., pp. 500 and 501.

and our application of atomic and molecular hypotheses to problems in heat, elasticity, and cohesion is essentially based on statistics of average conduct. Corpuscles in each other's presence are supposed to obey certain laws of motion, but no explanation has hitherto been given of these laws. So it is with vital units; they vary, why they vary we know not, and we *explain* nothing by attributing it to bathmic influences. As we can predict little or nothing of the individual atom, so we can predict little or nothing of the individual vital unit. We can deal only with statistics of average conduct. We have laws of variation and laws of heredity, in themselves quite as general and as definite as the majority of those we meet with in physics."

I may perhaps take this opportunity to explain that I have used the term biometric theory advisedly, and that the definition of it that I have had before my eyes is not merely "the application of exact statistical methods to the problems of biology,"* but the aspect of vital phenomena, just quoted from the "Grammar of Science," which prompts that application.

And I believe that I am justified in including under the term "biometric" both Pearson's and Galton's theories which, though in one respect they are radically different,† resemble each other in regarding heredity as a mass-phenomenon and in treating it by the statistical method.

The Mendelian, on the other hand, with a new application of experiment, is a biological demon who, "perceiving" and "handling the separate" units themselves, tries to find out their properties by mating them with other units. But, here again, I need not expatiate on the closeness of the parallel I have suggested when we

* *Nature.* Oct. 27, 1904. P. 626.

† Karl Pearson. *Biometrika.* Vol. III., pp. 110 and 111.

have these words from the champion of Mendelism in this country* :—"In the Mendelian method of experiment the one essential is that the posterity of each *individual* should be traced separately. If individuals from necessity are treated collectively, it must be proved that their composition is identical. In direct contradiction to the methods of current statistics, Mendel saw by sure penetration that masses must be avoided."

There is one direction in which my parallel may seem at first sight to be incapable of being pushed very far; it may be urged that we never can have any knowledge of the individual, but only of kinds of individuals, because in single cases it is impossible to eliminate the attributes which are due to chance: so that Mendelian methods are more to be compared with chemistry, which tests the property, not of units, but of masses of units which are known to be all the same.† But this fact does not in the least lessen the closeness of the parallel, for we have no reason to believe that the demon, if his attributes are as "essentially finite as our own," would have or need any knowledge of the individual molecules, but merely the ability to classify them into—say—ten classes, ranging from very fast to very slow, and to close his door according to their speed and direction. This point does not seem to be of much importance, but I did not wish, by not referring to it, to appear to have overlooked it.

One result, which seems to me to follow naturally from the truth of my comparison, is that it is unreasonable to apply, as has often been done, the criteria of

* Presidential Address to Section D, Brit. Assoc., 1904, in *Nature*, August 25, p. 409.

† *Cf.* "The breeding-pen is to us what the test-tube is to the chemist"—same Address, p. 409, 1st column; and cf. *Reports to Evol. Com. Royal Soc.*, I., p. 159.

either theory to a set of facts in which the conditions, on which that theory is true, do not obtain ; and the manner in which materials for the study of heredity are collected by Mendelians is so different from those employed by biometricians that this is very rarely, if ever, the case.

From this it follows that the naturalist who sets out to attack the problem of heredity will not as in the past collect his facts and then see whether they fit the one theory or the other, but will make it his first duty to decide whether he will attack it from the point of view of the physicist or the demon, from the outside or from the inside. If he decides on the former, he may if he wishes, breed his material, but he will find a great deal ready to hand in the records of matings of, for example, greyhounds, racehorses, and men. If he decides on the latter, it is almost indispensable that he should breed his material for himself. That is why biometricians are concerned with 'ancestry,' and Mendelians with 'posterity.' Yet these are not two things, but one thing, looked at from opposite ends. But there is a difference between ancestry and posterity, namely that the latter only can be dealt with by the method of experiment.

A confirmatory sidelight on the truth of my comparison is thrown by the consideration that of the two men whom I have quoted as representing the rival theories of heredity, the biometer is a mathematician, while the Mendelian is a zoologist: and it is entirely in accord with expectation that the former regards the phenomena of heredity from that point of view which does not presuppose knowledge of the unit, while the latter is concerned with the properties of the individual organism.

If we could imagine the demon and the physicist incapable of appreciating each others point of view we could understand the contempt each would have for the clumsy methods and erroneous opinions of the other.

And though we can perhaps understand the Mendelian declaring as he slides the latch of his breeding-pen that "Operating among such phenomena the gross statistical method is a misleading instrument; and, applied to these intricate discriminations, the imposing Correlation Table into which the biometrical Procrustes fits his arrays of unanalysed data is still no substitute for the common sieve of a trained judgment;" and that "nothing but minute analysis of the facts by an observer thoroughly conversant with the particular plant or animal, its habits and properties, checked by the test of crucial experiment, can disentangle the truth;"* and appreciate the point of view of the Biometer marshalling his vast arrays when he contends that it is "better to use the purely descriptive statements of Galton and Pearson than to invoke the cumbrous and undemonstrable gametic mechanism on which Mendel's hypothesis rests,"† I do not see that we have any right to remain blind any longer to the fact that the contradiction of their respective theories is only apparent, and is due to the radical difference in their points of view.

* Pres. Address to Sect. D. *Nature*, August 25, 1904, p. 408.

† *Nature*, Sept. 29, 1904, p. 539.

APPENDIX.

Facts.	Mendelian Interpretation.	Biometric Description.
"Versuche über Pflanzen-Hybriden," by Gregor Mendel. *Verhandl. naturforsch. Ver. in Brünn*, vol. 4, 1865. Abhandl. p. 1. Transl. into Engl. in "Mendel's Principles of Heredity," by W. Bateson.	(i.) Mendel, G., p. 72 in Engl. transl. by Bateson. (ii.) Bateson, W. Mendel's Principles, p. 57 et seq.	Weldon, W. F. R. *Nature*, vol. 70, p. 539.
"Versuche mit Kreuzungen von verschiedenen Rassen der Hausmaus," by G. von Guaita. *Ber. d. naturforsch. Gesell. Freiburg*, x., 1898, p. 317. Zweite Mitth., etc., *Ibid.* xi., 1900, p. 131.	(i.) Bateson. W. *Proc. Zool. Soc.*, 1903, vol. ii., p. 86—88. (ii.) Castle, W. E. *Proc. Amer. Acad. Arts and Sci.*, vol. 39, no. 8, p. 231, Table II.	
"L'Hérédité de la Pigmentation chez les Souris" (3me Note), by L. Cuénot. *Arch. de Zool. exp. et gén.* 1904 (4), vol. 2. *Notes et Revue*, no. 3. pp. 45—56.	Cuénot, L. loc. cit.	Weldon, W. F. R. *Nature*, vol. 70, p. 539.
"On the result of crossing Japanese waltzing with Albino mice," by A. D. Darbishire. Four Reports. *Biom.*, vol. 2, pp. 101, 165 and 282. vol. 3, p. 1.	(i.) Bateson, W. *Proc. Zool. Soc.*, 1903, vol. ii., p. 88. (ii.) Castle, W. E., and Allen, G. M. *Proc. Amer. Acad. Arts and Sci.*, vol. 38, no. 21. (iii.) Bateson, W. *Nature*, vol. 67, pp. 462, 585; 68, p. 33.	(i.) Darbishire, A. D., loc. cit. (ii.) Weldon, W. F. R. (α) *Biom.*, vol. 2, p. 286. (β) *Nature*, vol. 67, pp. 512, 610; 68, p. 34.

Manchester Memoirs, Vol. xlix. (1905), *No.* 7.

VII. Experiments on the Relation between Uniform Compressive Stress and Permanent Strain in Wrought Iron and Steel.

By W. C. POPPLEWELL, M.Sc., A.M.Inst.C.E.

(Communicated by Mr. Francis Jones, M.Sc., F.R.S.E.).

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In a Paper communicated to the Manchester Literary and Philosophical Society in 1893, Dr. (then Mr.) T. E. Stanton described a series of experiments for determining the relation between tensile stress and the permanent strain it produced in bars of wrought iron and steel. By plotting the logarithms of the stresses and of the corresponding strains, Dr. Stanton found that the relation was given by an expression of the form—

$$p = C \cdot e^k$$

where p is the stress on the bar, e the ratio of the elongation to the original length, and C and k constants varying with the material tested.

In 1899, Dr. G. Wilson communicated to this Society the results of similar experiments on copper bars, the relation following the same general law, but having different values for the constants C and k.

In order to see how far this same law holds for compressive stresses and their permanent strains the author carried out a number of tests at the Yorkshire College in 1899 upon bars of steel, wrought iron, copper, gun metal, and aluminium, and found that the law is sensibly the same for compression as for tension.

March 24th, 1905.

In the present paper a number of further tests on wrought iron and steel compression specimens are described.

Eight specimens were tested, four being of mild steel, and four of wrought iron of average quality. The test specimens, which were of cylindrical form having a height

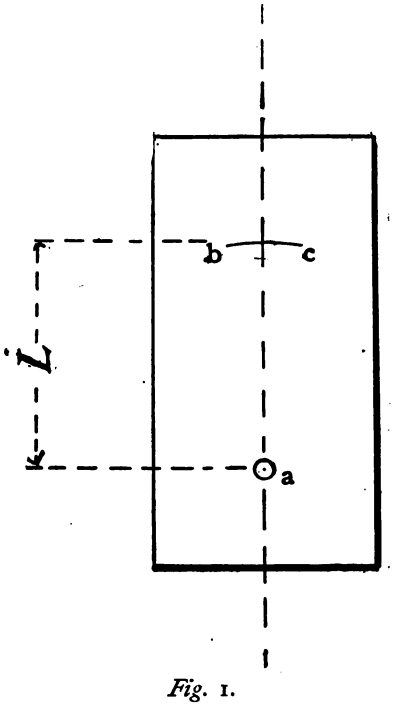

Fig. 1.

twice the diameter, were placed between the compression dies of a testing machine and successive definite loads applied. The form of the bar is shewn in *Fig.* 1.

Each load was allowed to remain upon the bar for about twenty minutes: after this it was taken out of the machine and the permanent set determined. In every case the length of the bar between its flat ends was

measured by means of the vernier calipers both before and after the application of the load. The ratio of the decrease in length to the original length was taken as the strain.

In compression experiments this method of determining permanent strains from end measurements alone has the disadvantage of giving rise to errors caused by the departure of the bar from its original cylindrical form under loads beyond the yield point.

In the case of a tension bar originally parallel, the tendency is for the bar to retain its parallel form when loaded far beyond the yield point, but in short compression specimens of plastic material which are being compressed between dies having plane parallel surfaces, it is found that the effect of the immediate contact between the specimen and the dies is to retard the radial dilatation in the immediate vicinity of the dies. This is probably to some extent due to the great friction set up between the surfaces in contact. It is found that at loads not greatly exceeding the yield point the specimen retains its parallel form in its middle portion for about one half its entire length, and tapers off to a smaller diameter towards the ends. This is shewn in *Fig.* 2. At higher loads the parallel portion disappears, and the specimen becomes barrel-shaped. In the present tests care was taken not to carry the loading far enough to destroy the parallel state for about one half the length.

When a bar begins to taper at the ends the permanent strain, instead of being uniform throughout the length of the bar is found to be greater towards the middle than at its ends. The consequence of this variation is that measurements of strain taken between the extreme ends are likely to be incorrect and misleading.

In order to overcome the difficulty arising from this

cause the author, in the case of most of the bars, adopted means for taking both end measurements and measurements between lines scribed upon the surface of that portion of the bar which was likely to remain sensibly parallel during the time of the test. The precise way of doing this was as follows: a fine centre punch dot *a Figs.* 1 and 2, was made upon the surface of the bar about

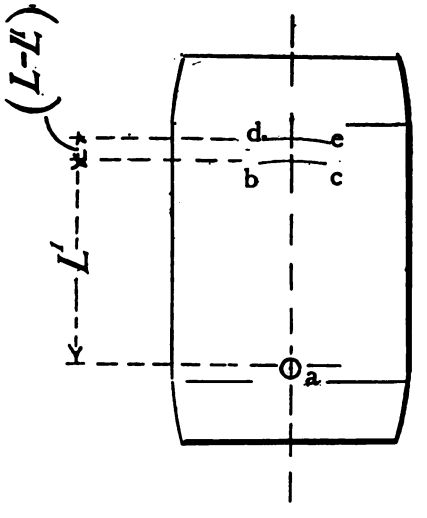

Fig. 2.

one centimetre from one of its ends. A pair of dividers were set to a radius of three centimetres, and a circular arc *b*, *c Figs.* 1 and 2, was struck with this radius with the centre-dot as centre, the mark being made upon that portion of the bar towards its other end. This gave a fixed distance of three centimetres marked upon the surface of the bar. After a load had been applied to the

bar sufficiently great to produce permanent set, the bar was taken out of the machine and a new arc *d*, *e Fig.* 2, struck from the same centre, the dividers having still the same radius. The distance between the first and the second arcs, measured along a line parallel to the axis of the bar gave the diminution of length caused by the imposed stress. The actual measurements between the arcs were made with a micrometer microscope. As the lines were very fine and were scribed on clean metal, it was found that the measurements could be made with a considerable degree of precision.

After each application of the load a new arc was struck with the original radius and a micrometer observation taken. In some of the tests two sets of readings were taken, one on each side, while in others three sets were taken.

If l is taken as the original length, and l' as the shortened length, then :—

$$\text{(the permanent strain)} = e = \frac{l - l'}{l}$$

The corresponding stress is p, which is the load on the bar divided by its area at the moment when it is sustaining the load in question; this is calculated from the length between the gauge lines on the assumption that the volume of the bar remains constant. It is known that the variation in the density of metals under stress is small and may be neglected for the present purpose. If l is the original length and a the original area, then the initial volume is $l \times a$. Similarly l' and a' are the corresponding values for the load in question, and $l' \times a'$ the volume. These two being assumed to be equal

$$a' = \frac{a.l}{l'}.$$

From this the stress

$$p = \frac{W}{a'} = \frac{W.l'}{a.l} = \frac{W}{a}(1-e).$$

In the present experiments, for each load imposed the observed quantities were the load in tons and the shortening of the specimen, and from this latter the permanent strain e was calculated. The initial area a was already known, so that the actual stress was easily calculated from the above expression. In all the results given the calculations were made in this way, the shortening being determined in some cases by end measurements only, and in others by both end and surface measurements.

In the following tables are given the main results for the eight specimens tested. Four of these bars were of average wrought-iron, and the remaining four were of mild steel. On each of the eight tables the results given are, besides the initial dimensions, the loads imposed W, the corresponding stresses p, the strains e, and the two constants occurring in the fundamental equation. These two last were found by plotting the logarithms of the strains as abscissæ and the logarithms of the corresponding stresses as ordinates; the points so obtained were found to lie on a straight line whose slope gave the value of the index constant k. The only remaining unknown in the equation for each load was the second constant C which was separately calculated for each load.

TABLES.

TABLE I.—Compression test of a specimen cut from a bar of average wrought-iron. No. I.

Original length, $L = 2{\cdot}228$ ins. Diameter, $d = 1{\cdot}125$ ins.

Value of k, from diagram $= 0{\cdot}251$.

End measurements only taken.

W	e	p	C
21·2	0·0175	20·836	57·52
22·2	0·0211	21·843	57·56
23·2	0·0251	22·736	57·33
24·2	0·0287	23·622	57·58
25·2	0·0327	24·497	57·82
		Mean value of $C =$	57·56

TABLE II.—Compression test of a specimen of wrought-iron similar to No. 1, but not from the same bar. No. 2.

$L = 2{\cdot}246$ ins. $d = 1{\cdot}131$ ins.

$k = 0{\cdot}265$.

W	e	p	C
18·2	0·0142	17·853	55·09
19·2	0·0169	18·785	55·38
20·2	0·0201	19·702	55·48
21·2	0·0241	20·587	55·27
22·2	0·0280	21·479	55·41
24·2	0·0374	23·185	55·40
28·2	0·0611	26·345	55·27
		Mean value of C =	55·33

TABLE III.—Compression test of specimen cut from 1¼ in. bar. No. 3.

$L = 2{\cdot}244$ ins. $d = 1{\cdot}123$ ins.

End measurements only. $k = 0{\cdot}172$.

W	e	p	C
19·0	0·0196	18·75	53·57
21·0	0·0272	20·521	53·73
22·0	0·0316	21·409	53·88
25·0	0·0486	23·850	53·47
27·5	0·0659	25·759	53·62
30·0	0·0842	27·591	53·42
		Mean value of C=	53·61

TABLE IV.—Specimen cut from low grade merchant bar wrought iron. No. 4.

$L = 2{\cdot}030$ ins. $d = 0{\cdot}998$ in.

Side measurements, $k = 0{\cdot}174$. End measurements, $k = 0{\cdot}172$.

W	e	p	C	e	p	C
20·2	0·0223	25·253	49·7	0·0172	25·365	51·02
22·2	0·0352	27·334	49·63	0·0290	25·563	50·61
24·2	0·0517	29·336	49·71	0·0440	29·581	50·87
26·2	0·0715	31·096	49·74	0·0610	31·456	50·87
28·2	0·0950	32·622	49·61	0·0823	33·083	50·88
Mean value of C =			49·68		=	50·82

TABLE V.—Specimen turned from a bar of average mild steel. No. 5. Specimen annealed before testing.

$L = 2{\cdot}021$ ins. $d = 0{\cdot}999$ in.

Side measurements, $k = 0{\cdot}234$. End measurements, $k = 0{\cdot}239$.

W	e	p	C	e		
18·2	0·0177	24·033	62·01	0·0149	24·344	63·98
22·2	0·0308	27·423	61·90	0·0269	27·504	63·18
24·2	0·0423	27·423	62·06	0·0374	29·689	63·21
27·2	0·0633	32·472	61·95	0·0564	32·712	63·37
	Mean value of C =		61·98		=	63·43

TABLE VI.—Bar of mild steel similar in all respects to the last. No. 6.

$L = 2{\cdot}021$ ins. $d = 0{\cdot}999$ in.

Side measurements, $k = 0{\cdot}268$. End measurements, $k = 0{\cdot}264$.

W	e	p	C	e	p	C
18·2	0·0206	22·731	64·34			
20·2	0·0275	25·038	65·52	0·0230	25·154	68·09
22·2	0·0375	27·234	65·63	0·0300	27·448	69·26
24·2	0·0492	29·323	65·72	0·0390	29·635	69·79
31·2	0·1138	35·254	63·17	0·0870	36·308	69·26
				0·1180	38·442	67·58
Mean value of C =			64·87	=		68·77

TABLE VII.—Specimen turned from mild steel bar similar to 5 and 6. No. 7. Annealed.

$L = 2{\cdot}013$ ins. $d = 0{\cdot}999$ in.

Side measurements, $k = 0{\cdot}238$. End measurements, $k = 0{\cdot}233$.

W	*e*	*p*	*C*	*e*	*p*	*C*
22·2	0·0360	27·278	59·18	0 0283	27·555	63·24
24·2	0·0503	39·392	61·05	0·0368	29·703	64·13
26·2	0·0636	31·342	61·11	0·0491	31·747	64·08
28·2	0·0790	33·098	60·56	0·0637	33·644	63·93
30·2	0·0980	34·714	60·33	0·0810	35·367	63·51
32·2	0·1153	36·241	61·61	0·0989	36·907	63·26
		Mean value of C =	60·64		=	63·70

TABLE VIII.—Specimen turned from mild steel bar similar to 5 and 6. No. 8. Annealed.

$L = 2{\cdot}004$ ins. $d = 0{\cdot}999$ in.

Side measurements, $k = 0{\cdot}264$. End measurements, $k = 0{\cdot}255$.

W	e	p	C	e	p	C
20·2	0·0280	25·026	64·27	0·0240	25·386	64·81
22·2	0·0370	27·246	65·04	0·0330	27·359	65·28
24·2	0·0491	29·323	64·97	0·0435	29·499	65·62
26·2	0·0607	31·333	65·45	0·0565	31·499	65·54
30·2	0·0943	34·858	65·06	0·0870	35·140	65·51
		Mean value of C =	64·96		=	65·35

TABLE IX.—Shewing in a general form the main results of all the experiments.

Material.	Number.	*k* Side.	*k* End.	*C*. Side.	*C* End.
High grade Wrought Iron.	1.	.....	0·251	.....	57·56
,, ,,	2.	.....	0·265	.....	55·33
,, ,,	3.	.....	0·267	.....	53 61
,, ,.	Mean	.....	0·261	.....	55·30
Low grade Wrought Iron.	4.	0·178	0·172	49·68	50·82
Average Mild Steel, annealed.	5.	0·234	0·230	61·98	63·43
,, ,, ,,	6.	0·268	0·264	64·87	68·77
,, ,, ,,	7.	0·238	0·233	60·64	63·70
,, ,, ,,	8.	0·264	0·255	64·96	65·35
,, ,, ,,	Mean	0·251	0·245	63·11	65·31

In addition to the above table IX. the accompanying diagram, *Fig.* 3, has been prepared. This contains the logarithmic plottings for all the specimens, the logarithms of the strains as abscissæ and the logarithms of the corresponding stresses as ordinates. The zero line for the strain logarithms is the same for all the cases, but the zero lines for the stress logarithms has been placed at various heights so as to separate the curves and prevent confusion.

Referring to the results as shewn by the general Table and by the diagram, it will be seen that the values of k, as shewn by the slope of the lines, vary somewhat from the value obtained in the tension experiments of Dr. Stanton, namely, 0·25, being in some cases below this value and in others exceeding it. The probable reasons for this were mentioned when referring to the difficulties attending compression experiments of this kind, and it may be regarded as probable that, if plastic compression tests could be made on longer bars with the loads applied quite centrally, results more uniform and more nearly agreeing with the tension results would be obtained.

The values of the second constant C will be seen to exceed those for the tension experiments both in the case of the iron and the steel, the difference for the results of the iron and the steel being about the same.

A notable exception is to be found in bar 4. The results in this case are abnormal both as regards k and C. It will be seen that the specimen in this case was smaller than 1, 2, and 3, and was of a very different quality of iron. Apart from these two facts it is difficult to account for the discrepancy.

A further point which is worth noting is that the values of k are higher and those of C lower where the

LOGARITHMIC CURVES OF STRESS & STRAIN.

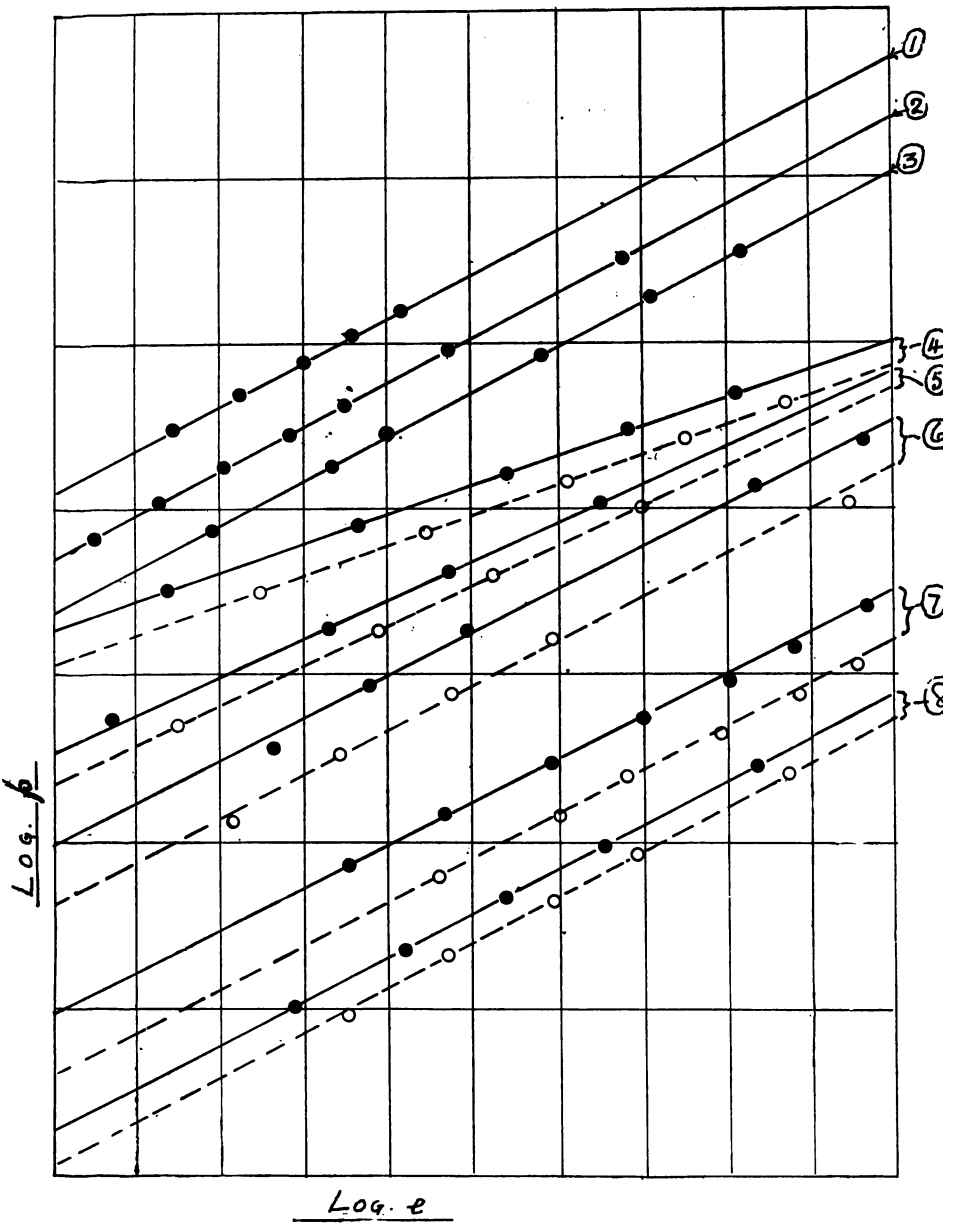

FIG. 3.

results are obtained from surface measurements near the middle of the bars than where obtained from end measurements. In this respect they more nearly approach the tension results, which would seem to indicate that the correct way of making determinations of this kind on compression specimens, is by means of surface measurements.

The experiments described were carried out in the Engineering Laboratory of the Yorkshire College, Leeds, and in the Materials Testing Laboratory of the Manchester School of Technology.

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VIII. On the Occurrence in Britain of the Pacific Eider (*Somateria v-nigrum*, Gray).

By CHARLES OLDHAM.

Received and read February 7th, 1905.

On December 17th, last year, Mr. Fred Stubbs, the Secretary of the Oldham Field Naturalists' and Photographic Society, received a drake Eider in the flesh from W. J. Clarke, a Scarborough dealer who supplies amateurs with freshly-killed birds for stuffing. The black chevron on the chin at once suggested to Mr. Stubbs that the bird was not a Common Eider, *Somateria mollissima* (Linné), and a reference to such ornithological works as he had at hand convinced him that it was referable to the Pacific Eider, *S. v-nigrum* Gray, a species not hitherto recorded for Europe. He at once wrote to the dealer for further particulars, and by the same post wrote to ask if I would like to see the bird before he skinned it. Taking advantage of his kind offer, I was able to handle the bird in the flesh on the following day. It is a male in full adult plumage, and taped 24½ inches from the tip of the bill to the end of the tail; the wing (measured in a straight line from the carpus to the tip of the longest primary) is 11 inches. The bill of the Common Eider is green, and the legs and toes dull green. The bill of the Pacific Eider is said to be bright orange in life (1). Mr. Stubbs told me that in his example the colour had faded even since the previous day, and when I saw it on December 18th the bare spaces at the base of the bill were dirty yellow, the webs of the feet yellowish green, and the toes

darker green. The tail feathers are a more intense black than in the Common Eider. Apart from the distinct V-shaped mark on the chin, the Pacific Eider differs from *S. mollissima* in the extent and distribution of the pale green feathers of the occiput. In Gray's description of the species (2) it is stated that in the male the green of the occipital region extends in the direction of the eyes as a border to the black crown; and this character is shown in the plate by Wolff which accompanies the description. In the Orkney bird the green colour is restricted to the occiput, as in *S. mollissima*, but the green feathers form an incipient crest. The bare spaces at the base of the bill form more acute angles than in *S. mollissima*, as does the wedge of feathers in the centre of the upper mandible. In the freshly-killed bird the long creamy-buff scapulars were slightly rosy, though less so than the breast. This rosy tinge appears to be evanescent, as it is in many birds, *e.g.* the Goosander and Little Gull, and has already faded considerably.

Dr. Bowdler Sharpe, of the British Museum, to whom Mr. Stubbs submitted a description and sketches of the Eider, confirmed his identification, and after the bird had been skinned and set up, exhibited it on his behalf at the meeting of the British Ornithologists' Club on January 19th (3).

In the meantime the Scarborough dealer wrote to Mr. Stubbs to the effect that the Eider had been consigned to him in the ordinary course of trade by an Orkney wildfowler—whose name was withheld—and was forwarded to Oldham within half an hour of its arrival in Scarborough, without having undergone a scrutiny which might have revealed its identity. Enquiries made in Orkney, through an entirely independent channel, have elicited the information that the bird was shot out of a

flock at Graemsay by a wildfowler named George Sutherland, who noticed that it had a black V-shaped mark on the chin, was rather thick in the head and neck, and perhaps whiter than usual on the back, but did not attach any importance to these peculiarities. The exact date of its occurrence is uncertain, but the bird had obviously only been killed a few days when Mr. Stubbs skinned it.*

The history of the specimen is above suspicion, and the occurrence of the species in Orkney, a place so remote from its known habitat, the Behring Sea, is of great interest to ornithologists. Mr. Stubbs is to be congratulated not only on having added a species to the European avifauna, but on his acumen in determining the identity of the bird. He has generously presented it to the Oldham Public Museum.

It may not be out of place here to refer briefly to the distribution of the four species of Eider which constitute the genus *Somateria*, as given by Count Salvadori (1).

The best known species, *S. mollissima*, ranges from Iceland eastward to the shores of the Kara Sea ; it migrates in winter to the Baltic, the shores of the North Sea and the English Channel and occasionally strays to Southern Europe. The Nearctic form of this species, the *S. mollissima borealis* of A. E. Brehm, inhabits eastern Arctic America, including Greenland, south to North Labrador in summer, and to the Northern borders of the United States in winter. *S. dresseri*, Sharpe, occurs on the Atlantic coast of North America from Maine to Newfoundland and South Labrador, ranging south in winter to the Delaware and the Great Lakes. This species has wandered to Europe ; an example obtained by Mr. T. M.

* Mr. W. P. Pycraft's letter to *Nature* (vol. 71, p. 201), wherein it is erroneously stated that the Eider was obtained at *Scarborough* on December 16th, was written before the matter had been thoroughly investigated.

Pike in Holland is in Mr. Hart's museum at Christchurch, Hants (4). *S. v-nigrum* inhabits north-eastern Asia and north-western America east to the Great Slave Lake. These three species are all closely allied. The fourth, *S. spectabilis* (Linné), differs from them considerably in appearance, and has been referred by Coues to a distinct genus, *Erionetta*. It inhabits the arctic regions of the northern hemisphere, wandering occasionally to New Jersey, the Great Lakes, and California in America; and in Europe, rarely, to the British Isles, France, and Scandinavia.

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IX. On some habits of Bats, with special reference to the Lesser Horseshoe Bat (*Rhinolophus hipposiderus*).

By CHARLES OLDHAM.

Received and read February 7th, 1905.

Little is known of the duration and extent of the winter sleep of bats in this country, and most writers on British Mammals have contented themselves with general statements to the effect that these creatures spend the colder months in a state of torpor, but that a small bat, usually said, on quite insufficient grounds, to be a Pipistrelle (*Pipistrellus pipistrellus*) may sometimes be seen hawking for food on warm days even in December and January. The account given by Alcock and Moffat (1) of a Long-eared Bat (*Plecotus auritus*) which was under observation at Ballyhyland, Ireland, for some time during the winter of 1900-1 is much more to the point. These observers state that "hibernation in the case of the Long-"eared Bat, at any rate, is not as profound or as unbroken "as was at one time supposed, but is repeatedly interrupted; "and, apparently, this is liable to occur whenever the "thermometer rises above 46°F."

The Long-eared Bat hibernates in the tunnels of the disused copper-mines on Alderley Edge, where it may be found hanging from the roof or walls, or, more rarely, wedged into crevices in the sandstone rock. When living at Alderley I used frequently to search for bats in these tunnels during the winter—they do not resort to them at other periods—and I came to the conclusion that the winter sleep was not infrequently broken. The bats

probably feed at intervals on the flies, gnats, and moths which are to be found in great numbers in the tunnels during the colder months, even if they do not venture into the open air. A noticeable trait in the character of this and other bats in captivity is the predilection for certain resting places. Bats which I have had at large in my rooms would, when disturbed, return again and again to some chosen spot on a picture-frame or cornice; and the same thing probably occurs under natural conditions. Long-eared Bats in the Alderley mines, if not molested, were generally to be found on each successive visit in the precise spot where they had been previously observed, but this of course does not prove that they had not been on the wing in the intervals. I attempted to mark some by snipping fur from their backs as they hung, but, although at the most they only resented this treatment by moving slightly or sometimes snarling, they had always changed their quarters before my next visit, and even if not subsequently molested they sometimes shifted their ground a second or third time. This was also the case if I touched one of the bats ever so lightly. The behaviour of these marked individuals cannot therefore be adduced as evidence either that the bats habitually move or that their winter sleep is normally unbroken. I have visited the mines scores of times in winter, but only once saw a bat on the wing. On the evening of February 15th, 1901, one was flying in one of the tunnels. It may possibly have been an individual which had been taken from the tunnel some days previously and replaced on February 12th, and, if so, its activity proves nothing; but the fact that when I captured and killed it fæcal matter was present in its intestines shows that at any rate it had been feeding recently. The temperature in this tunnel at 9-30 p.m., as registered by a thermometer fixed to a walking

stick two feet from the floor, was 43° F.; the thermometer registered 31° F. in the open air at the same time. On the evening of February 9th the temperature was 40° F. in the tunnel and 31° F. outside. If a bat is hibernating in a crevice or suspended from the roof or wall where the rock is much broken, it may easily escape notice; but it is a conspicuous object when hanging in a place where the tunnel is cleanly cut through the sandstone rock, and I have more than once found individuals in situations which they certainly had not occupied when I visited the place shortly before. This clearly indicates some measure of activity during the winter. On December 24th, 1898, I found one of these bats in a conspicuous position in a tunnel which I had carefully searched on several occasions during the previous two months. On January 27th, 1899, I took one from a tunnel which I had been in repeatedly during the winter; I could not possibly have missed this bat had it then been where I found it. On December 24th, 1899, I found one in a spot which it certainly was not occupying when I searched the tunnel on December 10th. Similarly on February 2nd, 1900, January 4th, 1901, and January 7th, 1901, I found a Long-eared Bat where none had been a few days previously.

Even during their period of activity, from spring to autumn, the diurnal sleep of bats is profound. The heart beats feebly, respiration is diminished, and the temperature falls. The creature, if taken in the hand, feels cold and lifeless, and some time elapses before, with sneezes and spasmodic twitchings of the limbs, it emerges from its lethargy, an epitome of restless activity and pulsating life. The phenomena of normal sleep are intensified during hibernation; but, even if other proof were lacking that the winter sleep is broken, it is highly improbable that the vital functions would be so far in suspense

that food taken immediately prior to the bat's retirement in autumn would remain unassimilated in the stomach, or as fæcal matter in the intestines, until the resumption of an active existence in spring. The fact that Long-eared Bats taken at Alderley in winter often defecated soon after being roused from slumber appears to be additional evidence of their intermittent activity at that season.

Two other species, Daubenton's Bat (*Myotis daubentoni*) and the Whiskered Bat (*M. mystacinus*), hibernate in the Alderley copper mines, but they are met with less frequently than the Long-eared Bat. It is probable that in both the winter sleep is interrupted, but further evidence on the point is desirable. A Daubenton's Bat taken in one of the tunnels on December 15th, 1894, defecated shortly after capture. A Whiskered Bat was certainly not in the place where I found it on March 5th, 1903, on any of my several visits during the preceding winter. An example of this species which had been caught on the wing in a bakehouse at Alderley was brought to me on February 8th, 1901, but there was nothing to show how it had got into the place. Even if it had chosen the roof for its hibernaculum, the warmth of the bakehouse may have roused it into precocious activity, and little importance attaches to the occurrence.

There is good reason to believe that the winter sleep of the Lesser Horseshoe Bat (*Rhinolophus hipposiderus*) is not continuous. Professor J. R. Kinahan (2), who made some interesting observations on this species in certain caves in County Clare more than forty years ago, states that on April 1st he found two individuals which were certainly not in the same place on March 22nd. Caves which are occupied by this bat in winter are, in some cases at any rate, vacated during the summer months. Kinahan says that the Clare caves were untenanted in August, and

Millais (3) cites Mr. T. A. Coward to the effect that no bats were to be found in the Cefn Cave, near St. Asaph, in August, 1903, nor in the Tremeirchion Cave in July of the same year. The date of retirement of the Lesser Horseshoe Bat to its winter quarters is unknown, and some which were taken in a cave at Tal-y-bont, Carnarvonshire, on September 24th, 1904 (6), may have occupied the place only during the summer months.

Be that as it may, Mr. Coward found bats in the Cefn Cave on November 18th, 1903. Quantities of fresh excrement on the floor beneath the hanging bats showed that they had not relapsed into profound slumber immediately on taking up their quarters for the winter, and remains of a cave-haunting spider (*Meta menardi*) in the excreta seemed to indicate that they had fed in the cave itself. In one of the galleries he encountered two of the bats in flight, and three others were wakeful enough to take flight before he touched them. The temperature of the cave on this occasion was 46°F. It is possible that in the early winter these bats are more active than during the later period of retirement, but their winter sleep does not appear to be ever very profound. On April 4th, 1896, I went to Cefn with Mr. Coward and Mr. R. Newstead, of the Chester Museum. We wished to photograph one of the bats *in situ*, but either the light of our candles or the noise made it very nervous. It swayed from side to side during the operation, and finally unfolded its wings and attempted to escape, although we had not touched it. On March 4th, 1899, Mr. Coward and I visited the cave again. When we approached with lighted candles, but before we touched them, the bats evinced consciousness of our presence. Some of them swayed slightly, and one jerked itself round spasmodically several times, whilst two drew up their bodies by flexing the legs, which in this species

are quite straight during sleep. Excrement was voided by the bats that we took away with us, and two which we chloroformed on the spot had fæcal matter in the lower part of the intestine; one had also a little half-digested matter in the stomach.

The structural differences which have led systematists to separate the Horseshoe Bats (Rhinolophidæ) from the Vespertilionidæ, the family to which all the other British species belong, are accompanied by equally marked diversities of habit. The attitude of the creatures in repose is strikingly dissimilar. The photographs of Leisler's Bat (*Pterygistes leisleri*) and of the Long-eared Bat show that in these species, as in others of the Vespertilionidæ, the tail is bent downwards and forwards beneath the belly: the greater part of both dorsal and ventral surfaces of the body being, however, exposed. In the Long-eared Bat the enormous ears are folded away beneath the wings and only the tragus is visible. The fore limb is bent at the elbow, the upper arm being directed backwards and slightly outwards; the forearm is held parallel to it, but pointing in the opposite direction, whilst the fingers and their connecting wing-membrane are folded loosely along the sides of the body. The legs are flexed. In the Lesser Horseshoe Bat the legs, as already stated, are perfectly straight; the tail instead of being carried beneath the body is reflexed so as to cover the lower part of the back; the upper arms are laid diagonally across the back, the elbows meeting at the lumbar region where they touch the tip of the reflexed tail; the forearms, bent sharply at the elbows, are laid lengthwise along the back so that the wrists flank the ears on either side; and the fingers with their connecting wing-membrane are folded over the ventral surface of the body so as to completely envelop the creature with the

exception of its face and a narrow space on the back which is exposed by reason of the convex shape of the forearms. The ears are hardly visible, being partially folded as a Long-eared Bat's are when it is half roused. The Lesser Horseshoe Bat when taken in winter seldom survives for many days, and it is noteworthy that as the animal grows weaker the body is less completely enveloped in the flying-membrane, and in death the dorsal surface is usually exposed. Mr. Newstead's photographs (4) of the bats that we found at Cefn were taken after he reached home, and the exposed surface on the back of the bat is much greater than is the case under natural conditions. In a group of the bats which were hanging, in close proximity though without touching one another, from the roof of the Cefn Cave, I noticed that the distance at which the feet were held apart differed considerably, possibly in relation to their foothold.

Captive Lesser Horseshoe Bats frequently uttered a cry, *tchek*, *tchek*, both when in flight and at rest, which reminded me of the alarm-note of the Greater Spotted Woodpecker, though it was, of course, not so loud. Another cry has been described as a low chatter.

It is a popular fallacy that bats cannot walk, or at the best can only shuffle along awkwardly, on a flat surface. In reality, all the British species of the family Vespertilionidæ which I have had under observation can, despite the fact that their knees are directed backwards—a position unique among mammals—walk with ease, and their pace is often accelerated to a pattering run. If one of these bats is walking on a flat surface, the tail is decurved beneath the belly, but when it ascends a vertical object, such as a curtain or a rough wall, the tail is extended behind, and helps to support the bat, as do the stiffened tail-feathers of a Tree Creeper or Woodpecker. Millais

(3) is incorrect in his description of a bat's gait. He says, "The limbs are moved laterally; first the thumb on one "side is pushed forward, followed by the corresponding "hind-foot; then the other foot is raised high and brought "forward, and lastly the wing on that side is advanced." As a matter of fact, as may be seen from the photograph of a Long-eared Bat, the sequence of movements constitutes the typical quadrupedal walk. First a hind-foot is advanced, then the fore-limb on the same side, followed by corresponding movements of the hind and fore-limbs on the opposite side. The Lesser Horseshoe Bat, on the other hand, seems to be incapable of walking on a flat surface. I have had several under observation at different times. These groped behind them with their feet, seeking some vertical surface, and readily climbed the side of a wooden box, ascending backwards with the assistance of their thumbs. Their only mode of forward progression was a series of awkward leaps of an inch or so in length, made with wings half spread, and legs extended helplessly backwards. After each leap they fell with a thud prone on the table. When on the flat this species carries the tail erect.

Another popular error, repeated *ad nauseam* in works on Natural History, is that bats cannot rise on the wing from a flat surface. All the British species with which I am acquainted take wing with ease, not even running forward to gain an impetus, but springing cleanly into the air as a Mallard does from the surface of a pool. The Lesser Horseshoe Bat is no exception. When lying prone it bounds into the air and is on the wing at once. I have seen one take flight from the bottom of a box three inches deep and not more than five inches wide.

I have called attention elsewhere (5) to the way in which some of the Vespertilionidæ secure their prey by

thrusting the head into the pouch formed by the decurved interfemoral membrane. Judging from the small size of this membrane in the Lesser Horseshoe Bat and the position in which it is usually carried—either erect or recurved over the back—it is probable that the habit does not obtain with that species, although Millais (3) asserts that it does with the Greater Horseshoe Bat (*Rhinolophus ferrum-equinum*). The Lesser Horseshoe Bats which I have had under observation have never survived captivity long, and have usually refused food, but I induced one that I obtained in Kent's Hole, Torquay, in April, 1901, to eat a few mealworms. Whether held in my hand or hanging suspended from my finger, the bat carried its tail recurved over its back and made no attempt to tuck the insects into the interfemoral membrane, but twice it bent its head beneath its body and apparently thrust it for an instant into one of its half-folded wings.

Lesser Horseshoe Bats when liberated in a room exhibit astonishing powers of flight. They lack the bold dash of the Noctule (*Pterygistes noctula*), and their actions are comparatively slow and fluttering, but they are able to make their way with unerring certainty amongst the furniture and into recesses, sometimes exploring the walls as if to find an exit, but never touching an object with their wings. I have even seen them pass beneath a sideboard raised less than three inches above the floor. They often sail on outstretched motionless wings for a foot or eighteen inches. I have never been able to make out how this species carries its tail in flight, whether erect, recurved, or extended straight behind. The legs show very distinctly against a white ceiling when the bat is viewed from below, but this may be due to the comparative shortness of the tail and not to its being erect or recurved. In the Vespertilionidæ the tail in flight is

carried quite straight, in a line with the body, as in Natterer's Bat (*Myotis nattereri*), or more or less decurved, as in the Noctule, the Whiskered Bat, and other species.

The Long-eared Bat, the Pipistrelle, and indeed all the Vespertilionidæ which I have had in captivity, alight on a vertical surface, such as a wall, a picture-frame, or a curtain, by pitching head uppermost. They then shuffle round instantly, and hang by their feet, in a convenient posture for another flight. But the Lesser Horseshoe Bat is infinitely more adroit. Immediately before it reaches the wall, or the object on which it desires to rest, it turns a somersault, timing its action with such nicety that it clutches the object with its feet, and is at once in the attitude for taking flight again. The bat by performing this manœuvre can suspend itself, in the act of alighting, from a horizontal surface such as a cave roof, as readily as from a vertical wall. Two individuals which I had under observation used after each flight to disappear beneath a couch, where I always found them suspended from the webbing which supported the seat. By lying on the floor with my head under the couch, and then disturbing the bats, I was able on their return to witness this feat of aerial gymnastics, which is perhaps unequalled among the higher animals. Mr. Coward informs me that a Natterer's Bat which he had at liberty in his study used, as a rule, to alight in the normal manner, by pitching head upwards, but that in order to settle on the tine of a deer's antler on the wall, it sometimes adopted the tactics of the Lesser Horseshoe Bat. This, however, it did with less agility, and but indifferent success, for it often failed to secure a foothold, and fell.

After alighting, and when hanging at rest, the Lesser Horseshoe Bat often bends its head upwards and backwards, and turns it from side to side, as though taking

stock of its surroundings, though whether the animal can see at all, in the ordinary sense of the word, is another matter altogether.

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(4) NEWSTEAD, R. "On the Position of the Lesser Horseshoe Bat, *Rhinolophus hipposideros*, Bechstein, during Hibernation." *Zoologist* (4), vol. 1, pp. 537—538, 1897.

(5) OLDHAM, CHAS. "Whiskered Bat (*Myotis mystacinus*) in Captivity." *Zoologist* (4), vol. 3., pp. 49—53. "The Mode in which Bats secure their Prey," *t. c.*, pp. 471—474, 1899. "Observations on the Noctule," *op. cit.*, (4), vol. 5, pp. 51—59, 1901.

(6) OLDHAM, CHAS. "Lesser Horseshoe Bat (*Rhinolophus hipposiderus*) in Carnarvonshire." *Zoologist* (4), vol. 7, p. 430, 1903.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 1. Lesser Horseshoe Bat in repose, ventral aspect.
Fig. 2. ,, ,, ,, ,, ,, , dorsal aspect.
Fig. 3. Leisler's Bat in repose, dorsal aspect.
Fig. 4. Long-eared Bat walking.

Figs. 1, 2 and 4 from original photographs by Robert Newstead.

Manchester Memoirs, Vol. xlix. (1905), *No.* **10**.

X. On the Temperature Co-efficient of Electrical Resistivity of Carbon at Low Temperatures.

BY

H. MORRIS-AIREY, M.Sc.,

AND

E. D. SPENCER.

Received and Read March 21st, 1905.

The alteration of electrical resistivity with temperature has been, in the case of most metals, very carefully studied, the general result being that the resistance of metals increases with rise of temperature. Dewar and Fleming* who have made the principal measurements at low temperatures find that the resistance of metals continues to decrease as the temperature falls, and they estimate that at the absolute zero, the resistance either vanishes entirely, or possesses an exceedingly small value.

A remarkable contrast to this behaviour occurs in the case of carbon. In the pure crystalline state (diamond) and in clean charcoal, carbon is practically an electrical insulator, but in the graphitic state or in the form of a coke, it conducts moderately well, its resistance, however, decreasing as the temperature rises. It has been pointed out by Beetz† that this anomalous behaviour of carbon is the same as that of many conductors (*e.g.*, iron filings,) when tested in the form of a loose powder and subjected to slight pressures. The conductivity of such a mass, apart from the nature of its material, depends solely on the number and extent of the contact surfaces. On decreasing the temperature, the individual particles become smaller, thus destroying some points

**Phil. Mag.* 1893, 36, p. 271.

†*Pogg. Ann.* 3, 1860, p. 629.

April 17th, 1905.

of contact with their neighbours, and increasing the resistance of the mass as a whole.

The great variation of the resistance of carbon in its different structures have led to the neglect of this element except in the case of high temperatures where a knowledge of its resistance was of commercial value. It seemed, however, of interest to examine some particular variety of carbon, and trace its variation, with temperature, to determine whether its resistance still increased at the same rate as the temperature became lower, or whether it finally behaved like a metal.

The conductors selected for the test were filaments * taken from Ediswan incandescent lamps; they were about 10 cms. long, and had a diameter of cross section of about ·00355 cms., and a resistance of 1,000 ohms at ordinary temperatures. The specific volume resistivity (*i.e.*, the resistance between opposite faces of a cube of the material having 1 cm. edge) was calculated from determinations of resistance on the assumption that the dimensions did not alter with the temperature, sufficiently to produce an effect comparable with that observed. The problem was then to measure the resistance of a filament of carbon of known dimensions, maintained at various low temperatures and to determine those temperatures. The latter measurements were made by observing the resistance of a platinum thermometer which had been previously standardised. This consisted of a metre of pure platinum wire, diameter $\frac{1}{10}$ mm. and resistance 20 ohms. wrapped in the form of a spiral on a small rod of some insulating material. The carbon loop was soldered by means of its platinum terminals to two stout copper wires, and the

* These are made by carbonising the precipitate obtained on passing a fine jet of a solution of cotton in zinc chloride into alcohol. The pores are filled up by "flashing" the filament in benzine vapour and platinum terminals attached by depositing carbon on the junctions.

platinum thermometer placed as close to it as possible, its ends being soldered to two similar copper leads.

Various methods have been suggested for the maintenance of low temperatures, one of the most recent depends upon the fact that a solenoid of wire with its ends dipping into liquid air encloses a space whose average temperature exceeds that of the liquid air by an amount depending on the length of the solenoid. Evidently, although the temperature at any point may be constant, it is a very great drawback to have the temperature varying from point to point.

The first method adopted was that used by Dr. C. H. Lees in his work on thermal conductivity at low temperatures. The carbon and platinum were immersed in liquid air, which is a non-conductor of electricity, and observations taken alternately of the resistances of the platinum and carbon, the time at which each observation was completed being noted. The resistance box used, which was kindly lent by Dr. Beattie, was made by Nalder Bros., and was provided with dial switches instead of plugs for varying the resistances. With this we were able to make determinations of resistance very quickly.

The liquid air rapidly boils away and the apparatus heats up to the temperature of the room. Curves are then drawn, connecting the alteration of resistance of both platinum and carbon with the time, and by interpolation the resistance of the platinum can be found at the instants when the resistance of the carbon was determined. Knowing the resistance of the platinum at 100°C. and 0°C., the temperature on the platinum thermometric scale corresponding to a resistance R of the platinum spiral, is found from the equation—

$$\text{pt.} = 100. \frac{R - R_0}{R_{100} - R}$$

It was found that the results obtained before the liquid air had quite evaporated were not consistent, observations made on different days showing wide deviations (see *Fig.* 1). The cause seemed to be that whilst the coils were only partially immersed in the liquid, the temperature fluctuated very much. The method was then slightly modified and the final arrangement is shewn in *Fig.* 2.

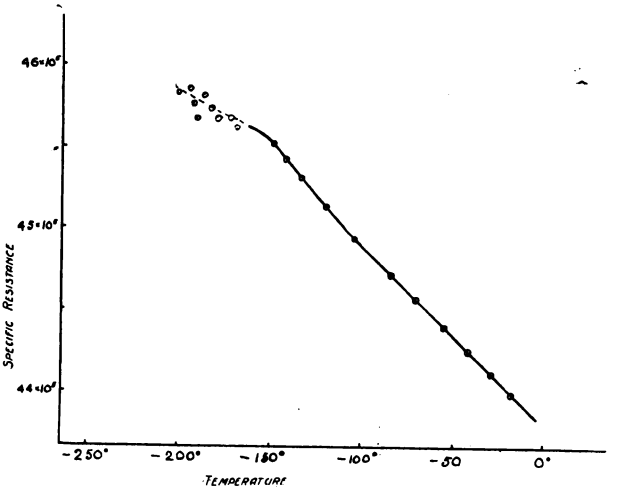

Fig. 1.

The carbon loop and platinum thermometer were carried down into a thick brass cylinder, which was supported by rods fastened to the wooden cover of the apparatus. Liquid air was poured in and replenished at intervals until the brass cylinder had been cooled down to the temperature of liquid air. Measurements of the resistance were then made, and when these gave steady values, the liquid air was poured out and observations of the resistances made as quickly as possible. Owing to the large heat capacity of the cylinder, the rise in

temperature was steady and comparatively slow. The determinations of resistance being made at the rate of two or three per minute, we were able to make between 100 and 150 observations before the temperature had risen to 0°.

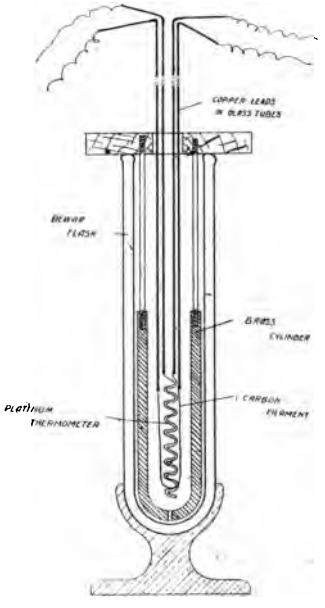

Fig. 2.

Curves were then plotted as before, connecting the resistances with the time. A typical curve is shewn in *Fig.* 3.

The small fluctuations in the curves were sometimes accidental, due to handling of the apparatus during the experiment. Occasionally they were produced intentionally to test whether the two coils were taking up the temperature of the enclosure at the same rate. It will be noticed that a fluctuation on the one curve is always

accompanied by a corresponding one on the other, the two occurring at exactly the same time, thus shewing that both coils are affected at the same time by temperature changes, so that we can assume them to be at the same temperature at any instant during the experiment.

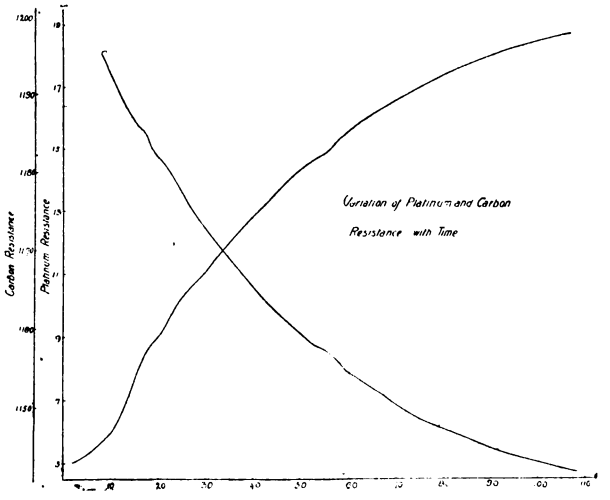

Fig 3.

The table on page 8 shews the values of the specific resistance of carbon (ρ) at various temperatures expressed in platinum degrees *pt.*

The curve in *Fig.* 4 shews the result graphically. The curve is practically a straight line until a temperature of -150° is reached, when there is a decided deviation, the curve returning, however, to a point on the straight line again at the temperature of liquid air (-182°C.).

In the experiments of Dewar and Fleming the resistance of carbon was determined only at three points below zero, one of which was the boiling point of liquid air and the other two being points on the straight portion of the curve. The deviation from the straight line curve

was thus undetected. Such irregularities in the curves are to be expected if we follow the analogy of the loose powder conductor.

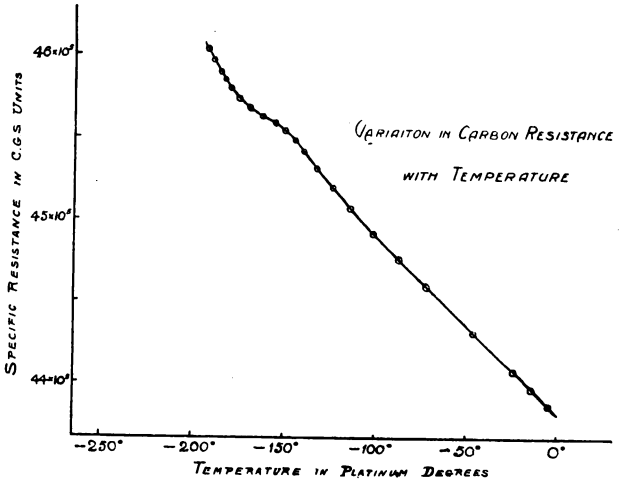

Fig. 4.

After a certain amount of contraction has taken place, there must occasionally come a readjustment of the relative positions of the particles which would become evident in such a curve as the above one. Measurements of the coefficient of expansion of carbon at these low temperatures would probably decide whether the analogy still holds here.

pt.	ρ	*pt.*	ρ	*pt.*	ρ
− 197·3	4612 × 10^3	− 134·9	4536 × 10^3	− 70·7	4459 × 10^3
− 195·0	4609	− 131·0	4532	− 67·7	4455
− 192·7	4605	− 128·2	4528	− 64·0	4451
− 191·0	4601	− 124·7	4524	− 60·4	4447
− 188·8	4598	− 121·3	4520	− 57·0	4444
− 187·2	4594	− 118·0	4517	− 53·4	4440
− 185·8	4590	− 115·1	4513	− 50·2	4436
− 183·9	4586	− 111·9	4509	− 47·0	4432
− 181·8	4582	− 108·5	4505	− 44·1	4428
− 178·6	4578	− 105·8	4501	− 41·0	4424
− 175·0	4574	− 102·4	4497	− 38·1	4420
− 170·7	4570	− 99·5	4494	− 34·6	4417
− 165·2	4567	− 96·6	4490	− 30·7	4413
− 159·7	4563	− 93·7	4486	− 28·6	4409
− 154·6	4559	− 90·8	4482	− 22·2	4405
− 149·8	4555	− 87·4	4478	− 18·6	4401
− 146·0	4551	− 84·0	4474	− 14·2	4397
− 143·2	4547	− 80·8	4470	− 10·9	4394
− 140·0	4543	− 77·2	4467	− 7·3	4390
− 137·9	4540	− 74·0	4463	− 4·0	4386

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XI. On Nevillina, a New Genus of Foraminifera.

By HENRY SIDEBOTTOM.

Received and read March 21st, 1905.

MILIOLIDÆ.

MILIOLININÆ.

Nevillina, gen. nov.

Test free, elongate, more or less pyriform, circular in transverse section, the final chamber completely embracing the previous one. Aperture circular, complex, formed by numerous incurved lamellæ, meeting centrally.

Nevillina coronata Millett, sp.

Biloculina coronata, Millett, *Journ. R. Micr. Soc.*, 1898, p. 263, pl. 6, figs. 6, *a*, *b*, *c*.

Test elongate, more or less pyriform, circular in transverse section. Aperture circular, complex, formed by numerous incurved lamellæ, meeting centrally.

The test in the early stages of growth is slightly compressed, and is either triloculine or biloculine, afterwards each succeeding chamber entirely embraces the preceding one. These last chambers are attached to each other at one end of the shell, and their direction of growth alternates, that is to say, they are put on first at one end and then at the other. The shell-wall is thin, smooth, white and polished, and when mounted in Canada balsam and viewed by transmitted light, shows the usual light-brown colour.

April 27th, 1905.

Mr. Millett's description of *Biloculina coronata*, in the above reference, reads as follows:

"Test fusiform, chambers few and inflated, sutures depressed, aperture circular, surmounted by a series of incurved lamellæ, which approach or inosculate over the centre of the aperture. Shell-wall thin, translucent, and much wrinkled, length 0·58 mm." He also adds "It is very rare, being represented by a solitary specimen from station 18."

It is evident to me, judging from the range of specimens that I have found, and from Mr. Millett's figures and description, that his solitary specimen is an immature (and probably malformed) example of the species which I found in the adult state, and for which I now create the new genus *Nevillina*, thus associating with it the name of my brother-in-law, Mr. Nevill, of Bramall Hall, Cheshire, to whom I am indebted for so many dredgings. These specimens were obtained from dredgings made by Captain Lunham, of the S.Y. "Victoria," for Mr. Nevill, and were given to me by the latter for examination.

If I am right in my conclusions (and they are confirmed by M. Chas. Schlumberger, of Paris, who, with his usual kindness, examined my section, drawings, and specimens) it follows that Mr. Millett's example does not belong to the genus *Biloculina*, and may with propriety be transferred to the genus *Nevillina*.

It will be noticed that the arrangement of the chambers, and their plan of growth, are in some respects the same as in the Chilostomellidæ.

Localities. Port Blair, east side of Andaman Island; at entrance to the port, between Ross Island and the main island, 16 fms., Dec. 15, 1899.

Sulu roadstead, 12 fms., Feb. 27, 1900.

Remarks. Very strong tide sweeping through the anchorage. Many shoals, and reefs of growing coral in the Sulu sea, and many banks frequented by pearl fishers.

Mr. Millett's specimen came from the north-east coast of Sumatra.

EXPLANATION OF PLATE.

The figures are magnified 25 diameters.

Nevillina coronata Millett, sp.

Fig. 1. This specimen, when found, was broken, and in preparing for section became further fractured, the exposed internal test, however, was not damaged, *Fig.* 2 being a drawing of it, and the section *Fig.* 8, was made from it.

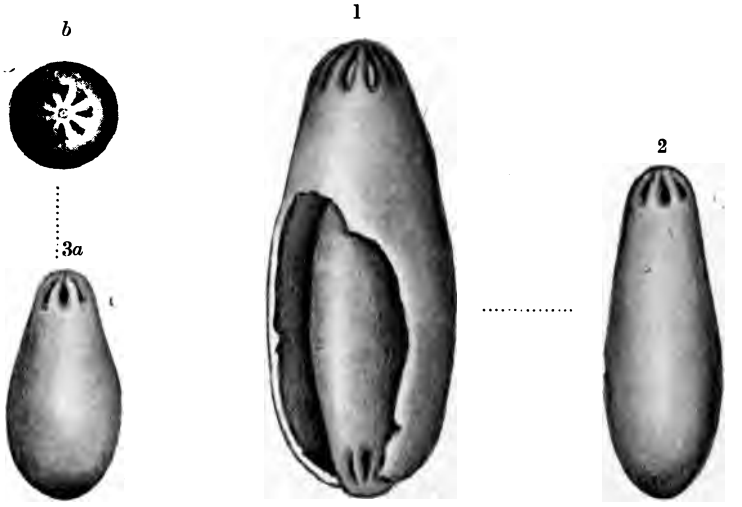
Fig. 3*a*, *b*. Side and end views of a smaller example.

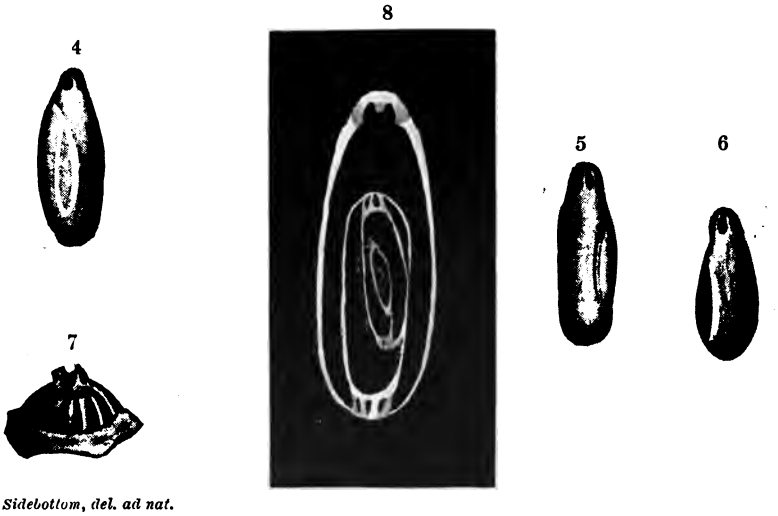
Fig. 4. Immature test in the triloculine condition.

Figs. 5, 6. Immature tests in the biloculine condition.

Fig. 7. Fragment of what must have been a very large specimen.

Fig. 8. Section of the test (*Fig.* 2) showing arrangement of its chambers in the various stages of its growth.





H. Sidebottom, del. ad nat.

Manchester Memoirs, Vol. xlix. (1905), *No.* **12.**

THE WILDE LECTURE.

XII. The Early History of Seed-bearing Plants, as recorded in the Carboniferous Flora.

By D. H. SCOTT, M.A., PH.D., F.R.S.,

Hon. Memb. Lit. & Phil. Soc., Manchester.
Honorary Keeper of the Jodrell Laboratory, Royal Botanic Gardens, Kew.

Delivered February 28th, 1905.

It has long been remarked that among the fern-like fronds which form so important and striking a constituent of the Carboniferous Flora as it has come down to us, a large proportion has never been found with any satisfactory indications of a Filicinean fructification. In fact a majority of the genera and species of fern-fronds (as we may shortly call them) are in this position, and *Pecopteris* is the only considerable genus which has so far consistently afforded evidence of fructification definitely referable to ferns.* A certain part of *Sphenopteris* is also known to have borne reproductive organs of the same general type, but this only applies to a fraction of the extensive genus.

In some cases, as in *Rhacopteris* and the Devonian *Palæopteris*, fructifications have been discovered which may be those of true ferns, but the real nature of which is still open to doubt. In many entire genera, as *Neuropteris*, *Alethopteris*, *Lonchopteris*, *Callipteris*, and others, including numbers of the commonest carboniferous species, no clear case of a fern-fructification has ever been observed; in most, the reproductive organs were wholly

* Even this statement now requires limitation. See below, p 15, footnote.

May 15th, 1905.

unknown (at least until within the last year or two); in a few cases such evidence as was available indicated a type of fructification very different from anything found among true ferns.

In all these numerous instances there were thus no real grounds for referring the plants in question to the Filicineæ, beyond the characters afforded by the frond, characters which, by themselves, are notoriously untrustworthy.

Although Stur, in 1883, excluded certain of these genera (*e.g.*, *Alethopteris*, *Neuropteris*, and *Odontopteris*) from the ferns, for the reasons indicated, the majority of palæobotanists were content to leave them in their traditional position, preferring to rely on positive characters however inconclusive, rather than on evidence which as yet was almost wholly negative. And in this they were not without justification, for the absence of any fern-fructification could always be provisionally accounted for by the hypothesis of dimorphism. Dimorphic ferns, or at least fern-like plants, are common in the Carboniferous Flora, and in cases where no Filicinean fructification was found on the ordinary leaves it was permissible to suppose that it might have been borne, as in *Osmunda*, for example, among recent ferns, on a specialized fertile frond, or portion of a frond, differing too widely from the sterile form to admit of identification.

Positive evidence as to the nature of some of the doubtful ferns of the carboniferous first came from anatomical investigation. When, just fifteen years ago, I paid my first visit to the late Prof. Williamson, in his house at Fallowfield, and there became acquainted with the treasures of his collection, the plant which perhaps most impressed me by the beauty and interest of its marvellously preserved structure was *Lyginodendron old-*

kamium. This plant has played a most important part in the growth of our knowledge of the Carboniferous Spermophytes, and it is from Williamson's early investigations of its structure, and that of an allied genus, that the first advance towards our present position must be dated. (Williamson, '73.)

The stem of *Lyginodendron*—the part first discovered—shows a structure which at first sight appears anything but fern-like (Williamson and Scott, '95). There is a large pith surrounded by a zone of wood and bast, with a recognizable layer of cambium between the two; the greater part of this zone has its elements arranged in radial series, and manifestly grew indefinitely in thickness, as in any Gymnospermous stem; the structure of the wood and bast generally is in fact much like that of the corresponding zones in a recent Cycad. Around the pith, however, several strands of primary wood may be distinguished, a structure not represented in the vegetative stem of any recent Gymnosperm. The development of these circummedullary strands was for the most part centripetal *i.e.* advancing towards the pith, (as shown by the position of the spiral elements, which are always the first to be formed). The primary strands pass out through the secondary wood into the cortex, where they form part of the vascular bundles which supply the leaves. These outgoing bundles have precisely the structure of the foliar bundles in recent Cycads. The presence of the primary strands of mainly centripetal wood around the pith suggested a search for corresponding structures in the axial organs of Cycads, and they have been found in certain genera in the peduncles of the cones, organs which in other respects also appear to have retained primitive characters (Scott, '97).

The evidence afforded by the stem-structure of

Lyginodendron indicated a clear affinity with Gymnosperms of the Cycadean group, rather than with ferns. Yet even in the stem fern-like features are not wanting. In favourable cases young stems have been met with, before the cambial activity had set in, and consequently at a stage when the primary structure existed unaltered. Such young stems present a striking similarity to those of the Osmundaceæ among recent ferns.

Williamson after a time succeeded in tracing the connection between the stem and its leaves, proving that the petioles of *Lyginodendron*, as he had suspected from the first, were identical with the fossil previously named *Rachiopteris aspera*, (Williamson, '90). The petioles, again, were found to branch freely, forming a highly compound rachis which bore characteristic, lobed leaflets. The form of the whole leaf was sufficiently clear in the petrified specimens to admit of its certain identification with the frond *Sphenopteris Höninghausi* Brong., long familiar in the form of impressions. (*See* Pl. III., Fig. 1). While the external morphology of the foliar organs was thus shown to have been wholly fern-like, the same proved to hold good for their structure. The vascular bundles of petiole and rachis are concentric, the bast surrounding the wood, just as in a typical recent fern. Thus, in spite of some differences in the minute histology, the foliage of *Lyginodendron oldhamium* turned out to be that of a fern, in structure, as well as in form. The roots, identified a little later, proved, like the stem, to show on the whole a Gymnospermous type of structure, though in their young condition they were not unlike those of certain ferns.

It thus became clear that one at least of the carboniferous plants with the foliage of a fern, presented characters indicating an affinity with Gymnospermous flowering plants, while at the same time its relationship to

the ferns was confirmed. During the last decade of the past century a number of cases of a similar combination of characters came under investigation (*e.g.*, *Heterangium*, *Protopitys*, *Medullosa*, *Calamopitys*) leading to the recognition, under the name Cycadofilices, appropriately suggested by Potonié in 1897, of an extensive group of Palæozoic plants intermediate, at least in vegetative characters, between ferns and Cycadophyta. For the moment we will continue to fix our attention on *Lyginodendron.*

As long ago as 1877 Stur had detected the fertile fronds of a *Sphenopteris* (*S. Stangeri*) scarcely distinguishable from the foliage of *Lyginodendron oldhamium*, and, as is now evident, itself belonging to a stem of the *Lyginodendron* type. The fructification described by Stur (*Calymmatotheca Stangeri*) is borne on a naked, branched rachis, and consists of lobed, cupule-like structures, interpreted by the discoverer as of the nature of an indusium opening by valves.* Although Stur's description has proved to have been perfectly accurate, the specimen by itself was insufficient to clear up the question of the true character of the fructification (Stur, '77).

The discovery of the seed of *Lyginodendron oldhamium* in 1903, will be fresh in the minds of many of my hearers. My friend Prof. F. W. Oliver had the happy inspiration to turn his attention to the unassigned seeds of the Coal-Measures, which for a good many years had been rather neglected by palæobotanists. In the course of his work he observed that one of these seeds, *Lagenostoma Lomaxi*, bore, on the husk or cupule which enclosed it, remarkable glands, agreeing exactly with those on

* Some authorities regarded the valves or lobes as sporangia, a view I was once inclined to accept. Observation of the actual specimen, however, proves that Stur's original interpretation was right.

the vegetative organs of *Lyginodendron*, while they are unknown in any other carboniferous plant. The investigation, which we then carried out in collaboration, left no doubt, from the evidence of structural identity and intimate association, that in this seed we have the female fructification of the plant *Lyginodendron oldhamium*, already so remarkable from the synthetic character of its vegetative structure (Oliver and Scott, '03 and '04.)

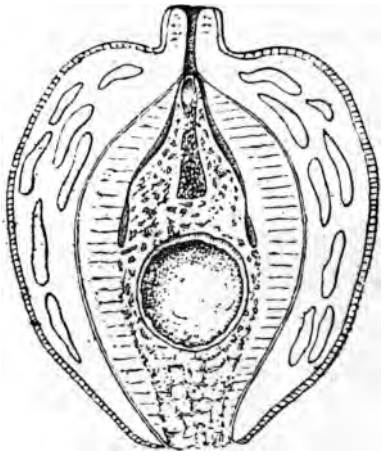
The discovery was in so far a surprising one, as it showed that the plant had advanced further along the line of spermophytic evolution than had been suspected from its other characters. The seed is a highly organized one (Pl. III., Fig. 2). Seated within a somewhat complex cupule, it possesses a curious chambered testa with an abundant vascular supply, and has a pollen-chamber, for the reception of the microspores, of more elaborate structure than that of any other known type of seed. Broadly speaking, and without going into details, the seed of *Lyginodendron* is on the level of that of a recent Cycad.

As is well known, a pollen-chamber, or excavation at the apex of the nucellus of the ovule, for the reception of the pollen-grains, is characteristic of the Cycads and the Maidenhair-tree (*Ginkgo biloba*) among recent plants. It was first discovered by Griffith in species of *Cycas*, at least sixty years ago. The illustrations of this structure (Text-figs. 1 and 2) are taken from Griffith's work published in 1852, several years after his death (Griffith, '52 and '45.)*.

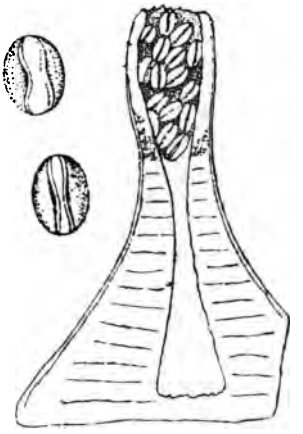
In *Lagenostoma* there is a central cone of tissue, projecting up the middle of the pollen-chamber, so that the cavity of the latter forms a bell-shaped crevice, in which the pollen-grains are sometimes found. (Text-fig. 3.)

* I am indebted to Sir William Thiselton-Dyer for calling my attention to Griffith's discovery, which has been too often overlooked.

They have been met with in great abundance in the pollen-chambers of two other species of *Lagenostoma*,

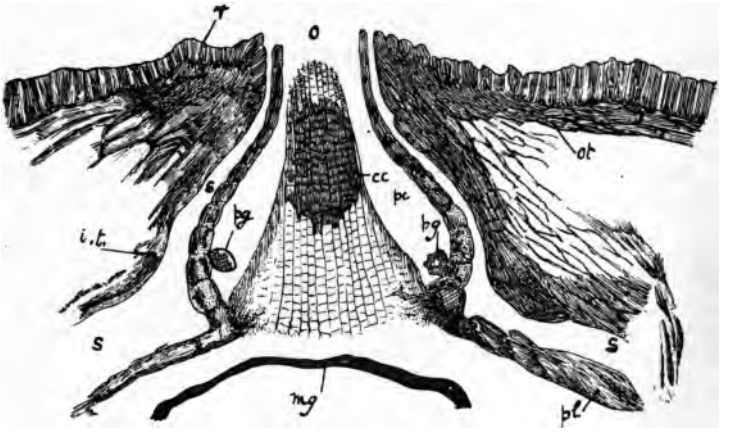


TEXT-FIG. 1. *Cycas* ovule, in longitudinal section, showing the outer and inner layers of the thick integument, the prominent micropyle, the nucellus, with a deep tubular cavity, the pollen-chamber, and below this the embryo-sac. Magnified.



TEXT-FIG. 2. *Cycas* ovule. Apex of nucellus, more highly magnified, showing the deep pollen-chamber full of pollen-grains in its upper part. To the left are two pollen-grains, more enlarged.
FIGS. 1 and 2 are from Griffith ('52).

L. ovoides, and *L. physoides*, especially the latter. The great number of pollen-grains occurring within the pollen-chamber of both recent and fossil plants possessing this mechanism, suggested to Sir Joseph Hooker the question whether insects, possibly attracted by a secretion from the glands in the case of *Lagenostoma*, might not aid in the fertilization, a point which has not yet been determined.



TEXT-FIG. 3. *Lagenostoma Lomaxi*, the seed of *Lyginodendron*. Apex of seed, in median longitudinal section, showing the upper part of testa, enclosing the pollen-chamber at the top of the nucellus. *ot*, outer layer of testa; *r*, palisade-cells; *i.t.*, inner layer of testa; *s,s*, cavity between testa and nucellus; *o*, orifice of pollen-chamber; *pc*, the actual pollen-chamber, lying between its outer wall and the central column, *cc.*; *pg*, *pg*, pollen-grains lying in pollen-chamber; *pl*, upper part of nucellus; *mg*, part of membrane of megaspore or embryo-sac; after Oliver; × about 70.

The pollen-grains found in the seeds have a characteristic, apparently multicellular structure, which, apart from its evident morphological interest, may prove of importance in enabling us to identify the corresponding male fructifications, not known with certainty as yet, either in the case of *Lyginodendron* or in that of any of the fern-like seed-plants of the carboniferous. Miss

M. Benson, F.L.S., has described a fructification, under the generic name of *Telangium*, regarded by her as not improbably belonging to *Lyginodendron*, with which it occurs in association (Benson, '04.) It consists of groups of long pointed sporangia, those of each group being partly united together as in the synangia of Marattiaceous Ferns. Perhaps the strongest argument adduced in favour of the reference of these sporangia to *Lyginodendron* is the striking agreement between the spores which they contain and the pollen-grains found in the pollen-chambers of *Lagenostoma.*

As regards the *Calymmatotheca Stangeri* of Stur, which, as we have seen, was a form of fructification belonging to a species of *Lyginodendron*, it is still uncertain whether the cupule-like organs originally contained the seeds or the pollen-bearing sporangia.

Returning to the seeds themselves, it may be pointed out that the two species *Lagenostoma ovoides* and *L. physoides*, though not yet referred to the plants which bore them, show such manifest affinity with the seed of *Lyginodendron oldhamium*, as to leave no doubt that they belonged to closely related plants. *L. ovoides* only differs in details from *L. Lomaxi.* The other species, *L. physoides*, is more peculiar, its most striking character consisting in the fact that at the free end of the seed, the testa breaks up into a sheath of free tentacles surrounding the apex of the nucellus, a condition not known in any other seed, recent or fossil. In neither case has a cupule yet been observed. We await a full investigation of these seeds at the hands of Prof. Oliver. Other seeds referable to the genus *Lagenostoma*, as at present constituted, have been found in the condition of impressions or casts. Two such species were described by Mr. Newell Arber last week before the Royal Society (Arber, '05). One of them, *Lagenostoma Sin-*

clairi, is of special interest for two reasons, first because each seed is enclosed within a definite lobed cupule, as in the seed of *Lyginodendron oldhamium*, and secondly because the seeds are borne on a branched rachis, best interpreted as a portion of a fertile frond, probably of the *Sphenopteris* type, though in the absence of leaflets no definite reference to any special form of sterile frond is possible.

The other species, *L. Kidstoni*, appears to have been borne in the same way on the finer ramifications of a naked rachis; in this case there is no proof that a cupule was present, but the form of the seed itself is beautifully preserved, and shows characters intermediate between those of the petrified species *L. Lomaxi* and *L. physoides*.

The species *L. Sinclairi* and *L. Kidstoni*, especially the former, are of importance as indicating how the seeds of the Lyginodendreæ were borne. In the case of *Lagenostoma Lomaxi*, the seed of *Lyginodendron oldhamium*, anatomical evidence shows that the pedicel immediately supporting the seed was of a foliar nature; in *L. Sinclairi* we see that this foliar organ formed part of the branched rachis of a modified fertile frond. The nearest analogy among recent plants is to be found in the genus *Cycas*, where the seeds are borne on foliaceous carpels, not aggregated into a cone, but springing directly from the main stem in rosettes alternating with those of the vegetative leaves.

So far as present evidence shows, the Lyginodendreæ bore fronds of the *Sphenopteris* type. The stems grouped under the generic name *Heterangium* have been found in connection, in the lower carboniferous deposits, with the fronds of *Sphenopteris elegans*, *S. Linkii*, and *S. dissecta*. The fructification is still unknown, but the anatomical characters, which proved a faithful guide in the case of

Lyginodendron, indicate that here also we have to do with fern-like Spermophyta, and not with true ferns (Williamson and Scott, '95).

The recent observations of Mr. David White, of Washington, show that the frond *Aneimites fertilis*, very near a *Sphenopteris* in form, bore organs which can scarcely be interpreted otherwise than as winged seeds (White, '04); similar seeds are associated with similar fronds in our own coal-measures, though here the evidence of continuity is still to be sought.

We may now pass on to another group, that of the Neuropterideæ, taking the family in a wide sense to include *Alethopteris*, *Odontopteris*, *Linopteris* and other genera, as well as *Neuropteris* the type-genus. It was fronds of this class which, as already mentioned, roused Stur's suspicions more than 20 years ago. In the case of some members of the Neuropterideæ, as in that of the Lyginodendreæ, we are now possessed of a fairly complete knowledge of the vegetative organs.

Examples of two of the genera are given in Plate I. (*Neuropteris heterophylla*) and Plate II. (*Alethopteris Davreuxi*). The fronds are of large size and repeatedly pinnate, those of *Neuropteris* often recalling a recent *Osmunda*, while *Alethopteris* resembles some species of *Pteris*.

The late distinguished French palæobotanist, M. B. Renault, whose loss we have recently had to lament, was the first to demonstrate the anatomical structure of *Neuropteris* and *Alethopteris* fronds, and to prove that, as Grand 'Eury ('77) had already suggested, their petioles are identical with the petrified specimens named *Myeloxylon* by Brongniart (Renault, '83). Weber and Sterzel ('96) further proved that these *Myeloxylon* petioles were borne on the complex stems described by Cotta in

1832 and named by him *Medullosa.** The relation of the various organs is very well shown in the British species, *Medullosa anglica*, discovered a few years ago (Scott, '99), in which the leaf-bases, with typical *Myeloxylon* structure, are still attached to the stem, with which the adventitious roots are also in connection. The foliage of this species was that of an *Alethopteris*, very probably identical with the well-known *A. lonchitica*. The stem, like that of the more highly organised ferns, contains several vascular cylinders (usually three in the British species) but each of these cylinders surrounded itself with a zone of secondary wood and bast, produced by the activity of a special cambium. Thus the structure of an old stem comes to simulate that of an anomalous Cycad, as is more especially apparent in some of the highly complex continental species. The structure of the petiole, with its numerous vascular bundles, has in almost every detail a Cycadean character, though in form and venation the fronds (as in the recent Cycad *Stangeria*) are like those of a fern. The root-structure also finds its nearest analogy in that of Cycadaceæ. Thus we recognize here also, a combination of Cycadean with Filicinean characters, the primary organization of the stem and the external characters of the frond pointing to ferns, while in all other respects the structure of Cycads is approached. On these grounds the Medulloseæ, like the Lyginodendreæ have been placed since 1897 in the class Cycadofilices. The Medulloseæ, founded on anatomical characters, and the Neuropterideæ, distinguished by the external features of the frond, are, to a great extent at least, co-incident, so that in this case also we have an important group of fern-like fronds, shown by their structure to have belonged to plants very different from true ferns.

* This discovery was originally made by Weber about the year 1880, but the evidence was not fully published till 1896.

Here again, it is only quite recently that definite evidence as to the fructification has come to light, enabling us to fix with something like certainty the systematic position of the family. Mr. R. Kidston, F.R.S., at the close of 1903, brought before the Royal Society his observations on *Neuropteris heterophylla;* he was able to show from specimens collected in the Dudley Coalfield, that large seeds, almost of the size of a hazel-nut, were borne on the frond, for, attached to the rachis supporting the seed, were the characteristic pinnules of this species of *Neuropteris* (Pl. III., Fig. 3.) (Kidston, '04). The seed, which has a fibrous testa, is placed by Mr. Kidston in the genus *Rhabdocarpus* as defined by Goeppert and Berger; it must not, however, be confounded with the very different seeds described under the same generic name by Brongniart, which probably belonged to the Cordaiteæ.

Thus we see that in this *Neuropteris* the fertile, seed-bearing frond was so little modified as still to bear recognisable leaflets like those of the sterile foliage—a fortunate circumstance, as it renders the demonstration of continuity direct and conclusive. It is an interesting fact that as long ago as 1887 Mr. Kidston had discovered another form of fructification in the same species of *Neuropteris*, which, though quite problematic at the time of its discovery, may not improbably prove to represent the pollen-bearing organs (Kidston '87). Mr. Kidston's discovery of the seed in a species of *Neuropteris* gives great probability to suggestions previously made as to the fructification of other members of the family. Evidence from association had led Mr. Hemingway in 1898 to believe that certain species of *Neuropteris* and *Alethopteris* bore seeds, *Trigonocarpon* among others, and Mr. George Wild had shown, in 1900, that the seed

Trigonocarpon olivaeforme, so frequently associated with *Medullosa anglica* or its Alethopteroid foliage, agreed with the vegetative organs of that plant in certain structural details. I feel little doubt myself that this attribution is correct, though more decisive evidence is needed. The genus *Trigonocarpon* includes some of the most familiar seeds of the English Coal-Measures, frequent both as casts and as petrified specimens. Most of the casts are merely internal moulds of the seed-cavity, as Williamson pointed out, but more perfect specimens, showing the testa and the form of the seed as a whole are also met with. The testa, as shown in the petrifactions, had a complex structure, the thick, hard, and ribbed inner layer being enveloped in a fleshy outer envelope. It was the agreement in structure between the external membrane of the fleshy envelope and the corresponding layers of the petiole in *Medullosa anglica*, which led Mr. George Wild to suspect that the seed and leaf might belong to the same plant (Wild, '00). A remarkable feature in the seed *Trigonocarpon* is the great prolongation of the winged micropylar tube, which considerably exceeds the body of the seed in length (Pl. III., Fig. 4).

Although it is only in the case of *Neuropteris heterophylla* among the Neuropterideæ that we have as yet direct and conclusive proof that seeds were produced, it is obvious that this cannot have been an isolated instance. If we further take into account the indications just mentioned in the case of *Alethopteris* and *Trigonocarpon*, the anatomical evidence demonstrating a clear relation of certain members of the family to Cycadophyta, and the constant absence of any sign of a cryptogamic fructification, it can scarcely be doubted that the whole of the Neuropterideæ, in so far as they constitute a natural group, were seed-bearing plants.

The argument from association, though of small weight by itself, has considerable value, when critically employed, as supporting more direct lines of evidence. We owe to M. Grand 'Eury, the veteran palæobotanist of St. Etienne, an extensive investigation of the distribution of Neuropteridean fronds and associated seeds in the upper and middle coal-measures of France (Grand 'Eury, '04). He is not only led to the conclusion that the Neuropterideæ generally bore seeds, and were, to use his words, primitive Cycadinæ with the fronds of ferns, but is able, as he believes, to assign definite types of seeds to particular species of the genera *Neuropteris*, *Alethopteris*, *Odontopteris*, *Linopteris* and others, on the evidence of constant and exclusive association. It thus appears that the numerous unassigned carboniferous seeds of the type of *Trigonocarpon* or the seed of *Neuropteris heterophylla* are likely, as investigation proceeds, to find a place among the fern-like genera.

To bring this part of our subject to a conclusion, all the evidence points to the inference that a large part (probably a decided majority) of the fern-like plants of the carboniferous flora were Spermophyta, allied most nearly to the Cycadaceæ among recent plants, but retaining, in their vegetative structure, clear indications of affinity with the ferns. For this great synthetic group the name Pteridospermeæ has been proposed.* (Oliver and Scott, '04).

* Since this lecture was delivered, M. Grand 'Eury has discovered, in the well-known species *Pecopteris Pluckeneti*, a new and striking example of a "seed-bearing fern." The specimens, which the discoverer most kindly allowed me to examine, show a multitude of small seeds (a species of *Carpolithes*) ranged along the pinnæ of the fronds, which scarcely differ from the ordinary vegetation form. In favourable cases the connection between the seeds and the rachis appeared evident.

The fact that a species referred to the genus *Pecopteris* should thus prove to be a member of the Pteridospermeæ is a surprising one, considering

It is manifest that the existence of the class Pteridospermeæ in Palæozoic times has an important bearing on the whole question of the evolution of the Phanerogamia. On the anatomical evidence alone it has been held for some years by many palæobotanists that the origin of Cycadaceous Gymnosperms, at any rate, was to be traced to the ferns (Scott, '00). Now that we know that the intermediate group on which this conclusion was based, included true seed-bearing plants, with seeds of the same type as those of Cycadaceæ, the case is so much strengthened as to be no longer open to dispute. The comparatively slight indications of fern-affinities presented by the recent and the Mesozoic Cycadophyta are accentuated to such a degree among the Palæozoic Pteridospermeæ, as to establish a clear connection with the fern-phylum.

This is in itself a conclusion of much importance. As all palæontologists are aware, the Cycadophyta, though now reduced to a small group, formed, in Mesozoic times, a dominant factor in the vegetation of the world. They were then not only an extensive, but a highly varied class of plants, embracing forms which, in the complexity of their fructification, nearly approached the Angiosperms themselves. In the Palæozoic rocks the remains referable to true Cycadophyta are scanty and limited to the upper beds, but those of the more primitive class Pteridospermeae are enormously abundant. Thus

the strong evidence for classing *Pecopteris* among Marattiaceous ferns. It must be remembered, however, that *P. Pluckeneti* is one of the Sphenopteroid species, and probably not a typical member of the genus. It was placed in a separate genus, *Dicksonitites*, by Sterzel, on account of the character of the "sori" (male fructifications?) which, however, are still imperfectly known (Sterzel, '83).

M. Grand 'Eury is publishing an account of his discovery in the Comptes Rendus of the French Academy of Sciences.

Note, added April 14th, 1905.

there is no longer any difficulty in accounting for the advent of the Cycadophytic vegetation which so rapidly established itself in the succeeding epoch. Its source is doubtless to be sought among the Pteridosperms, and through them may be traced back to ancestors with Filicinean affinities.

At this point, however, a word of caution is not out of place. Those who take the view which I am endeavouring to commend to you this afternoon, are accustomed to speak, for shortness' sake, of the origin of the Gymnosperms, or at least of the Cycadophyta, from ferns. It must, however, be remembered that seed-bearing plants, including both Pteridospermeæ and members of the more advanced family Cordaiteæ, can be traced as far back as the ferns themselves. They appear to have been well represented in the Devonian, and so far as I am aware, records of land-plants earlier than the Devonian are still too dubious to take into account. Further, the Pteridospermeæ, though so clearly related to the ferns by many of their characters, possessed, as we have seen, not merely seeds, but highly organized seeds. Their most striking peculiarity—and this extends to all known Palæozoic seed-plants—is the constant absence of an embryo, though the preservation is often so good that we should expect to be able to detect it if it had been there, as is the case in the Mesozoic *Bennettites*, where the embryo is well preserved. It is probable that the postponement of the embryonic development till germination began (a condition of which reminiscences persist in living Cycads) may really have been a characteristic of ancient seeds. But granting them this primitive character, the fact remains that the earliest known seeds were already so far advanced in their evolution as to leave little trace of their derivation from cryptogamic sporangia. Thus, properly speaking,

we have not yet been able to follow this ancient line of seed-plants to its *origin*. The ancestors of the Pteridospermeæ are still unknown, and may have differed in important respects from ferns as we now understand them. What we are entitled to say, on present evidence, is that the most primitive seed-plants known to us present close affinities with the ferns, and must have sprung, with them, from a common stock, while they show no indication of any near relationship to the other families of Pteridophyta.

It now remains for us to consider whether this conclusion may be extended to other groups of Palæozoic seed-plants.

Since the researches of Grand 'Eury ('77) and Renault ('79), nearly 30 years back, it has been known that the characteristic Gymnosperms of Palæozoic times were not, as had been previously supposed, Coniferæ, but belonged to a distinct family, that of the Cordaiteæ. The work which had been begun by Carruthers and Williamson was carried on with such brilliant success by the French investigators that we have been placed in possession of wonderfully complete data as to all the organs in certain plants of this group. The habit of the trees, the form of their leaves, the minute structure of leaf, stem, and root, the characters, both external and internal, of the male and female inflorescences, and the structure of the seeds have all been revealed. We have only to regret that the best of the available material seems to have been soon exhausted, and that our knowledge of the family has not been widened, to the extent we might have hoped for, by later researches.

The Cordaiteæ were lofty trees, with a tall erect shaft, terminating in a crown of branches bearing large, simple leaves, sometimes a yard or more in length. Some of the Conifers of the Southern Hemisphere, especially the large-

leaved species of *Agathis*, give us probably the best idea of the aspect of the Cordaiteæ, though the comparison is not a very close one.

The anatomical structure of stem and root has on the whole a Coniferous character, the wood being of the well-known *Araucarioxylon* type. The pith of the stem, however, was large, as in Cycadaceæ. The structure of the leaves resembled that of the leaflets of a Cycad. The male catkins bore, among their bracts, stalked tufts of elongated erect pollen-sacs, which may perhaps be most nearly compared, though very different in appearance, to the stamens of *Ginkgo*. The ovules were borne in small cones, or lax catkins, and appear to have been produced in the axils of bracts, each ovule perhaps terminating a short axillary shoot. The structure, both of the ovule and of the ripe seed, has been investigated. Here, as in *Lagenostoma* and other Pteridospermeæ, there is a pollen-chamber, in which the pollen-grains are found. It was in the case of *Cordaites* that M. Renault first observed the multicellular structure of the pollen-grains, and found reason to believe that their growth was continued after they became enclosed in the pollen-chamber of the ovule.

It is a fact of great interest that M. Renault in discussing the multicellular pollen-grains of Palæozoic seed-plants, suggested in 1896, that they might have discharged spermatozoids within the pollen-chamber to effect fertilization—a remarkable anticipation of the discovery of motile spermatozoids in recent Cycads and in *Ginkgo*, announced by Ikeno and Hirase a few months later. (Renault, '96.)

The seeds of Cordaiteæ are flattened, thus differing from the "radiospermic," *i.e.*, rounded or cylindric type, which appears to have characterised the Pteridospermeæ. In relation to the different form there is also a different

distribution of the vascular supply. In other respects there is a general resemblance in the seeds of the two groups; in the Cordaiteæ, as in the Pteridospermeæ, although the archegonia have been clearly seen, no sign of an embryo has been detected.

The Cordaiteæ evidently bore no resemblance in habit either to ferns or Pteridosperms, nor do we find in their structure any of those fern-like characters which are so marked in the latter class. Their inflorescences also are of a much more advanced nature than the fertile fronds of the fern-like seed-plants, or even than the floral organs of the Cycadaceæ. In the Cordaiteæ we have evidently to do with a well-characterised Gymnospermous family, far more remote from any Cryptogamic progenitors than the plants previously considered, though their geological record goes equally far back.

The Cordaiteæ, as we have seen, show plain indications of Cycadean affinity, especially in their foliar structure, and in the characters of the seed. Perhaps their nearest ally in the recent flora is the Maidenhair Tree (*Ginkgo biloba*), which agrees with the Cycads in its fertilization by spermatozoids and generally in the characters of the ovule and seed. At the same time it is impossible to ignore points of resemblance between the Cordaiteæ and the Coniferæ, in habit, anatomical structure, and to some extent in the floral organs.

Have we then any grounds for connecting this remarkable group with the same stock as the Pteridospermeæ, or must we suppose that it had a totally distinct origin, traceable, perhaps, to some different Cryptogamic phylum?

It has already been pointed out that the Cordaitean seed, though different in details from the Pteridospermous type, yet was not fundamentally distinct.

That no great weight can be attached to the difference in symmetry, bilateral in Cordaiteæ, radial, so far as we know, in Pteridospermeæ, is shown by comparison with recent Cycadaceæ, among which the seed is bilateral in *Cycas*, but radially symmetrical as regards internal structure in all the other genera of the order (Stopes, '04).

In other respects there is a general agreement in the organization of the seed between Cordaiteæ and Pteridospermeæ, as regards the vascular supply, the relation of integument to nucellus, the formation of a well-differentiated pollen-chamber containing multicellular pollen-grains, and the presence of archegonia, instead of a developed embryo in the ripe seed. It is difficult to imagine so near a correspondence having risen independently of relationship (Oliver, '03).

The question whether the testa of the Cordaitean seed represents a single or a double integument may best be left open for the present. Precisely the same doubt exists in the case of living Cycads, where Miss Stopes, who has found reason to believe that the integument is double, compares its outer layer to the cupule of *Lagenostoma Lomaxi* (Stopes, '04).

In the species of *Cordaites* investigated by M. Renault, there is little direct evidence from the anatomical structure indicating any connection with the Pteridospermeæ, though it must be borne in mind that the foliar structure, as well as the organization of the seeds, in their close agreement with corresponding features of Cycadaceæ, afford indirect evidence in that direction, for whatever tends to connect the Cordaiteæ with Cycads tends also to connect them with the group from which we believe the Cycads to have been derived. Comparative anatomy, however, furnishes a further line of evidence. One of the Palæozoic genera best known from an anatomical point

of view, is *Poroxylon*, investigated with wonderful thoroughness by Messrs. Bertrand and Renault nearly 20 years ago (Bertrand and Renault, '86). Here, as in *Cordaites*, the structure of all the vegetative parts of the plant is known with all the detail that could be desired, but we are as yet ignorant of the nature of the reproductive organs. The thick, simple leaves have a structure comparable in all essential points to that of the leaves of Cordaiteæ; as in them, the vascular bundles are like the foliar bundles of Cycads. The roots also resemble those of Cordaiteæ and have the typical structure of Gymnospermous roots. The stem, however, has essentially the structure of a *Lyginodendron* stem, that is to say, strands of primary wood, wholly or mainly of centripetal development, are present round the pith, and pass out in pairs, through the secondary tissues, to form part of the bundles supplying the leaves. Here then we have a clear combination of Cordaitean characters with those of a Pteridospermous genus. *Poroxylon*, however, has so far only been known from the Permian, and might thus be thought too late in appearance to illustrate the origin of so ancient a group as the Cordaiteæ. It is therefore of interest to know that quite recently a plant has been discovered by Mr. Lomax in the lower coal-measures at Shore, Littleborough,* in this county, which shows, in perfect preservation, all the essential characters of the French *Poroxylon*, and, so far as a preliminary investigation has shown, will prove to be a new species, or, at least, a close ally of that genus, from a much lower horizon than the other representatives of the group.

Further, stems have been known for some time of still greater age, belonging to lower carboniferous horizons,

* A locality remarkably rich in petrified plant-remains, now opened up to palæobotanical exploration by the generosity of the owner, Mr. W. H. Sutcliffe.

which show similar characters. The great trees of the genus *Pitys*, with wood of the Araucarian type, found by Witham of Lartington, on the Tweed, and at Craigleith, near Edinburgh, in the early days of fossil botany, have proved on re-investigation to possess strands of primary wood in their pith, which appear to be homologous with those found in *Lyginodendron* or *Poroxylon*. There is every reason to believe that *Pitys* represents the stems of ancient members of the Cordaitean stock. Thus it appears that there is a series of forms connecting the stems of the *Lyginodendron* type with those of typical Cordaiteæ as investigated by M. Renault (Scott, '02[1] and '02[2]). In fact, in the case of some of the lower carboniferous stems, the characters exactly hold the balance between the two groups, and it is only when evidence as to the character of the foliage is available that one can say to which they belonged.

Thus, taking into consideration both the seed-characters and those of the vegetative anatomy, there is every reason to believe that a real affinity existed between the Cordaiteæ and the Pteridospermeæ. The Cordaiteæ are so ancient that their origin lies further back than our records extend. But the evidence distinctly points to the conclusion that at some remote period they sprang from the same stock to which the carboniferous Pteridospermeæ belong, and consequently that they too, like the Cycadophyta, were ultimately derived from cryptogams allied to the ferns. Considering, however, the enormous antiquity of the Cordaiteæ as compared with the comparatively late appearance of true Cycadophyta, it seems probable that the two classes originated separately, and at very different periods, from the plexus of primitive, fern-like seed plants, which played so important a part both in Devonian and carboniferous times. While certain families

within this plexus seem to have made rapid progress, and in the Devonian period had already advanced to the rank of well-characterised Gymnosperms, the remainder long retained much of their primitive fern-like character, and it was only in much later days, perhaps far on in the carboniferous era, that they gave rise to seed-plants of a more modern type (Cycadophyta).

So far, then, as the great bulk of the Palæozoic seed-plants are concerned, their ultimate derivation from the Filicinean stock seems clearly indicated by all available evidence, and this conclusion, as we have seen, must be extended to the whole of the Cycadophyta, both Mesozoic and recent.

As regards the Coniferæ, more difference of opinion is likely to be found. Certain botanists, while accepting the fern-origin of the Cycadophyta and Cordaiteæ, have still preferred to trace the Coniferæ to a Lycopod ancestry. Others have drawn a distinction within the Order, and leaving the Taxaceæ with the Fern-phylum, have assigned the rest of the Conifers to the Lycopod line.

It is only in the latest Palæozoic deposits that true Conifers (*Walchia* and *Voltzia* being the chief genera) are known to occur. *Walchia* appears to show most affinity with the Araucarieæ, while *Voltzia* has been compared to the Taxodieæ, of which the gigantic Sequoias are the best known living representatives. We are not as yet in a position to trace clearly the relations of these early Coniferæ to the Cordaiteæ, but new light on the question may be hoped for from Mr. Seward's work, now in progress, on Araucarian Conifers. The complete identity in the structure of the wood between Araucarieæ and Cordaiteæ (which for many years led to the inclusion of the latter among Coniferæ) can hardly be without significance. This type of wood, characterized by the arrangement of

the pits in several series on the walls of the wood cells, was of wide distribution in Palæozoic times, extending to Pteridospermeæ, and even to some Ferns, as well as to Cordaiteæ. It is now almost limited to the Araucarieæ, certainly an ancient group, which may reasonably be supposed to have retained a primitive character.

The Araucarieæ, however, show clear relations to the rest of the Coniferæ, in the organization of their cones, and other characters, and it seems difficult to attribute a different origin to them from that of the remaining sub-orders, with the possible exception of the Taxaceæ. The latter family, however, itself shows, on other lines, some approximation towards Cordaiteæ, through the isolated type *Ginkgo*, as indicated by anatomical characters, and by those of both male and female flowers.

On the whole, then, although the indications are somewhat scanty, yet, such as they are, they appear all to point to an affinity between the Conifers generally and the Palæozoic Cordaiteæ, and through them with the Pteridospermeæ, and so in the last resort with the Fern-phylum in the broadest sense. I, at least, find it impossible to believe that the Coniferæ are an unnatural group, and that their various tribes can have been derived from totally different sources.

The final conclusion, then, to which, as I think, we are led on the basis of the evidence at present open to us, is that the Gymnospermous seed-plants generally are best regarded as in a broad sense, monophyletic, the whole class having been ultimately derived from the Pteridospermic stock, itself allied most nearly to the Ferns. In a narrower sense, however, we may still speak of the probable origin of the Gymnosperms as polyphyletic, for, as we have seen, there is reason to believe that their

different main groups sprang from the common, fern-like stock, at different times, and at different points.

It is an interesting fact that in a wholly distinct group from any we have been considering, that of the Lycopods or Club-mosses, seed-like organs were developed in some of the Palæozoic representatives. The two genera in which this has been established—*Lepidocarpon* and *Miadesmia* (Scott, '01; Benson, '02)—agree in having possessed a single functional megaspore or embryo-sac within the sporangium, and in the enclosure of the sporangium or nucellus by an integument, leaving an opening comparable to a micropyle. The whole organ, like a true seed, was indehiscent, and was shed entire. The analogies with true seeds are undoubtedly striking, but there is a total absence of detailed agreement with the seeds of the typical Spermophyta. The Lycopods, as shown not only by these characters, but by their complex anatomical structure, attained an extraordinarily high development in Palæozoic times. We cannot wonder that it was among them that the great French school of palæobotanists long sought the nearest affinities with the Gymnosperms. But striking as the analogies are, there is, I think, no proof that they are more than analogies. It appears that Lycopods, as well as members of the Fern series, acquired the seed-bearing habit in Palæozoic times, while approaching the higher plants in other features also. We have, however, no clear indication that they left any descendants among the Spermophyta that have come down to our own times.

One point that comes out clearly from the facts that we have been considering this afternoon, is that the balance of power among the plants of carboniferous times must have been very different from what we have been accustomed to believe. From the days of Brongniart onwards, the Palæozoic age, represented for our purposes by the

carboniferous flora, has been described as the Reign of the Higher Cryptogams. This description can no longer be maintained. If, as we have found reason to believe, half, or more than half, the so-called Ferns of those days were really seed-bearing plants, while many of the Lycopods had likewise assumed the seed-habit on a line of their own, it follows that at that relatively early period the Spermophyta had already put themselves on even terms with the Sporophyta, perhaps had begun to gain the upper hand. The outward aspect of a Carboniferous forest may, it is true, have been suggestive of some huge tropical fern-house, but this appearance would have been an illusion, for a great proportion of the plants of cryptogamic habit would prove, if we examined them more closely, to bear true seeds, or organs indistinguishable from seeds, on their fronds or cones.

In the flora of the present day it rarely happens (as in the classical case of the Cycad, *Stangeria*) that the habit of a plant leaves us in doubt as to its Cryptogamic or Phanerogamic nature. In the Carboniferous era such doubts would have been prevalent enough, and even if we called in structure to our aid, it would often have been hard to determine on which side of the boundary line a given plant was to be placed. The Lycopods with seed-like organs, for example, seem to have differed in no other respect from their still purely Cryptogamic relatives, and among the Fern-series there are plants well-known in their vegetative morphology and anatomy, as to the true position of which we are still completely in doubt. In fact, when we go back to the carboniferous flora, we are approaching a time when the distinction between seed-plants and spore-plants was not yet one of the great frontiers dividing up the vegetable kingdom.

It is one of the great triumphs of the French School

of Fossil Botany (although we may not accept their results in detail) to have first grasped the fertile idea that nearly related plants may lie, some on one side, some on the other, of the ideal Cryptogamic-Phanerogamic boundary. The demonstration that something like a debatable land once lay on this frontier, now so well delimited, is perhaps the greatest contribution which Palæobotany has yet made to the Theory of Descent.

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DESCRIPTION OF PLATES.

PLATE I.

Neuropteris heterophylla. Part of a large frond, showing a main pinna, with secondary pinnæ and leaflets. Nat. size. From a photograph by Mr. R. Kidston, F.R.S.

PLATE II.

Alethopteris Davreuxi. A species allied to *A. lonchitica.* Part of a large frond, showing the branching rachis, with main pinnæ, secondary pinnæ, and leaflets. Very slightly reduced. From a photograph by Mr. R. Kidston, F.R.S.

PLATE III.

Fig. 1. *Sphenopteris Höninghausi*, the foliage of *Lyginodendron.* Fragment of the highly compound frond, showing spiny rachis with pinnæ, pinnules, and small incurved leaflets. Nat. size. From a photograph by Mr. R. Kidston, F.R.S.

Fig. 2. *Lagenostoma Lomaxi*, the seed of *Lyginodendron.* Photograph from a model by Mr. H. E. H. Smedley, F.L.S., showing the seed in its cupule, which is lobed, and studded with capitate glands. Magnified about 5 diam. as compared with the actual seed when mature.

Fig. 3. *Neuropteris heterophylla.* Large ribbed seed, attached to a portion of the rachis, bearing characteristic leaflets. *cf.* Pl. I. × 2. From a photograph by Mr. R. Kidston, F.R.S.

Fig. 4. *Trigonocarpon Parkinsoni.* Small seed, showing cast of internal cavity and micropylar canal, the whole surrounded by the thick testa, which forms a broad wing on either side of the micropylar canal. Nat. size. From the type-specimen in the Hutton collection at Newcastle-upon-Tyne. For this photograph I am indebted to Prof. M. C. Potter, F.L.S.

NEUROPTERIS HETEROPHYLLA.

ALETHOPTERIS DAVREUXI.

Fig. 1.

Fig. 3.

Fig. 2.

Fig. 4.

Figs. 1 and 2. *Lyginodendron.*
Fig. 3. *Neuropteris heterophylla.*

Fig. 4. Trigonocarpon.

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XIII. Note on Chlorine.

By D. L. CHAPMAN, M.A.,

AND

C. H. BURGESS, M.Sc.

Received March 21st. Read April 18th, 1905.

The effect of certain impurities in retarding or preventing the combination of chlorine with hydrogen has been investigated in greater detail by the authors. After the discovery that ammonia is the main cause of what has been appropriately termed by Bunsen and Roscoe the 'induction period,' it was thought that other impurities which can react with chlorine in light might have the same effect. As far as we can judge this is not the case with ether, alcohol, and benzene. The experiments upon which this conclusion is based were performed in the following way. Two similar actinometers were filled with a mixture of hydrogen and chlorine in equal volumes. To one actinometer 5 c.c. of the so-called ammonia-free water were added, whilst into the other 5 c.c. of the same water containing a small quantity of the impurity whose influence it was desired to investigate were introduced. The two actinometers were symmetrically placed with respect to the standard light, and the movements of the index recorded. The induction periods were small, and the observed differences when alcohol, ether, and benzene were used so insignificant that we are forced to conclude that these substances will not prevent the action between hydrogen and chlorine.

As we have already stated in a previous communica-

tion to this society, if ammonia, or the products of the interaction of ammonia and chlorine, are present in the mixed gases, combination only occurs after the actinometer has been exposed for some time to light. Experiments have been conducted for the purpose of discovering to which possible chemical compound this effect is immediately due. Direct experiments demonstrated the negative effect of nitrous and nitric acid. Nitrogen chloride would appear to be indicated as the cause by the following experiment. A dilute solution of ammonia was saturated with chlorine, and divided into two portions. Five c.c. of the first portion were added to an actinometer containing hydrogen and chlorine, which was then exposed to light. The induction period was long. From the second portion the chlorine was removed as far as possible by exhaustion, and 5 c.c. of the resulting liquid introduced into a similar actinometer. The induction period was very short; and therefore the compound to which the induction period is immediately due belongs to that class of substances which are volatile, and being only slightly soluble in water, are readily removed by exhaustion. Nitrogen chloride fulfils these conditions.

In certain cases it was observed that even after the gaseous mixture had been exposed to light, until the rate of combination had reached a maximum, and the actinometer had subsequently been allowed to stand for some time in the dark, a second induction period resulted on re-exposure to light. This decay in the activity of the mixture is more noticeable when the actinometer contains water, with the purification of which from organic matter no special care has been taken. The phenomenon does not occur when pure water or a solution of ammonia in pure water is used. It is probably due to the presence of

substances, which are attacked by the chlorine in the dark with the production of the compound, which prevents the combination of hydrogen and chlorine in light. In support of this view, it may be mentioned that the phenomenon in question was particularly pronounced when a solution of aniline hydrochloride was used, the second induction period being in this case longer than the first.

It was at one time thought that sulphur dioxide acted in the same way as ammonia, although in a much less marked degree. Subsequent investigation has shown that this is doubtful, and that the small effect observed was probably due to small quantities of nitrogenous organic matter originally present in the water. This matter is being further investigated.

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XIV. On some Constituents of Manchester Soot.

By Professor EDMUND KNECHT, Ph.D., F.I.C.

Received and read May 2nd, 1905.

The coal burnt in Manchester and its immediate surroundings is chiefly what is known as a "fat coal," which, although possessing a high calorific value, is known to yield, especially when used in the household, an abnormally large proportion of smoke and soot. It is to this circumstance that we must ascribe the vitiated condition of the atmosphere in which we exist for the greater part of the year, with its attendant evil effects on the respiratory organs, the desolate appearance of plots of land in the city and its immediate neighbourhood, the dirty condition of all out-of-door objects, the enormous amount of labour involved in keeping the interiors of houses clean, and lastly, to a large extent, the inconvenience experienced by individuals and the trade and commerce of the city caused by such dense black fogs as we experienced last winter.

Having had occasion to examine during February, 1902, some samples of surface snow which had been collected in the centre of the city, and in one of its suburbs, it struck me that it would be of interest if we could obtain some further knowledge of the constituents (more particularly those of organic origin) of the smoky atmosphere we live in, and experiments were undertaken with this end in view, in the carrying out of which I was assisted for a brief period by Mr. Percy Gaunt and by Mr. Cresswell Milnes. Although I am conscious of the fact that the investigation was far from being complete,

circumstances at the time did not permit of the further working out of details, and as I do not see my way to enter into the matter again (at all events in the near future), I take the liberty of bringing before you the results which we have so far obtained.

It is popularly supposed that the visible products of the incomplete combustion of coal and other fuel consist merely of finely-divided carbon; and this view is frequently supported in works of a scientific or semi-scientific character. There can be no doubt that this view is to a large extent correct in the sense that these visible products contain finely-divided carbon, but that other solid constituents are met with in not inconsiderable amounts in the soot which is deposited from smoke, has been well known for a long time to the manufacturer of carbon blacks.

The manner in which smoke forms from coal burning in our open fire-grates cannot have escaped the attention of even the most casual observer. It will be quite evident from the voluminous disengagement of gases or vapours that in the first instance dry distillation takes place. Where such disengagement is moderate, the vapours take fire and burn with a bright luminous flame; but if the disengagement becomes violent, the vapours either do not burn at all, or only suffer partial combustion, and their bulk finds it way, mixed with a large excess of air, into the chimney. When the first violent disengagement of gas has ceased, the coal burns quietly with a lurid flame, from which no dry distillation products, but only products of incomplete combustion, result. From these considerations I think we may take it that our smoke and soot consist partly of dry distillation products and partly of the products of incomplete combustion, to which must be added the mineral matter, which is partly

volatilised by the heat of the fire, and partly carried away mechanically by the draught.

Our original idea of ascertaining the composition of coal smoke proper presented difficulties which we did not see our way to overcome, so we chose the next best expedient of subjecting ordinary chimney soot to a more exact examination. The first samples examined were taken partly from chimneys in my own house and partly from other chimneys, but were found to vary so much in composition, that it was ultimately decided to obtain an average sample from a dealer, and this subsequently served for all our quantitative experiments.*

In consequence of its constant exposure, while in the chimney, to a current of warm air, this soot may have lost some of its more volatile constituents, and these would in that case have escaped observation. Again, it is quite likely that in one and the same stack the composition of the soot will vary according to the distance from the fire, but this question was not gone into.

The methods employed for separating and isolating the constituents were similar to those which are used in the treatment of coal-tar. The soot was extracted with boiling dilute sulphuric acid, with the object of removing basic constituents; then with caustic soda, to remove acid constituents and phenols; and lastly with benzene, to extract the hydrocarbons. Modifications of this mode of procedure were also tried, for the sake of

*A large proportion of the household soot collected in Manchester is sold to dealers, who in their turn dispose of it for agricultural or horticultural purposes. I am informed that some is sold locally, but that the bulk goes to Kent, where it is used as a manure for hops. Its effective constituent as a manure consists of salts of ammonia. At the same time, however, it acts as an insecticide, and this property is possibly due to the presence of pyridine and allied bases. At any rate it is certain that its value as a manure cannot depend altogether upon the amount of ammonia it contains, as its price (3s. per cwt.) would be far too high in proportion to the percentage (10-15) of the latter.

convenience. Thus, in one series of experiments, the soot was first extracted with benzene, and the extract, after evaporating off the solvent, treated with sulphuric acid and then with caustic soda. In another case the soot was extracted with benzene, and this extract was treated with caustic soda only (previous experience having shown that practically none of the basic constituents were taken out by the benzene). The benzene extract was separated from the soda lye, and from the black tar which formed a middle layer, and in this case was the only portion further worked on.

Aqueous extract. In all the samples of Manchester soot which came under examination, it was found that the aqueous extract showed a strongly acid reaction, due to the presence of free sulphuric acid, which amounted on an average to about one per cent.* The aqueous extract contains practically all the ammonia and pyridine bases. By a tedious process of extraction, I succeeded in isolating from it both ammonium sulphate and ammonium chloride by purely mechanical means.

Sulphuric acid extract. 500 grms. soot were boiled for several hours with 4 litres dilute sulphuric acid, filtered, washed, and the united filtrates evaporated down to a quarter of the original bulk. A considerable quantity of a crystalline deposit thus separated, amounting to 9·5 grms. This was found on examination to consist of an impure calcium sulphate. It is noteworthy that the same deposit was obtained with all the Manchester samples worked on as well as with the Prague sample. It might have been taken for granted that the presence of calcium sulphate was due to the action of the sulphuric

* A sample of soot which came from a suburb of London (E.) also yielded a strongly acid aqueous extract, whereas a sample which I obtained from Prague (lignite coal) gave an extract which was neutral to litmus paper.

acid on the mortar in the chimneys, but the occurrence of this substance in surface snow would appear to indicate that the lime had come out of the coal. The filtrate from the calcium sulphate was of a clear light brown colour, and was found on analysis to contain ammonia equivalent to 10·7% ammonium sulphate on the weight of the original soot. This extract was not further examined.

Caustic soda extract. 1000 grms. soot were extracted as before with boiling dilute sulphuric acid and washed. The residue was then boiled for three hours with eight litres water and 200 grms. caustic soda. A dark brown liquid resulted, which was filtered off, and the acid constituents precipitated by acidulating with dilute sulphuric acid. The product thus obtained amounted to 109 grms. It was of a rich brown colour, and possessed a strong sooty smell. On heating it neither melts nor volatilises, but simply chars with evolution of but little gas. It resists nitration and sulphonation, and is soluble in boiling sodium carbonate. The solution in caustic soda is not precipitated by carbonic acid. In its general properties the substance (which is nitrogenous) would appear to resemble some of those indefinite brown organic substances which are classed as humic acid.*

A portion of the caustic soda extract, melted in the well known manner with sodium sulphide, yielded a sulphide colour which resembles in its tinctorial properties the best brands of Cachou de Laval, and dyes cotton in absolutely fast shades from a light fawn to a brown black, according to the amount of colour employed.

Benzene extract. The residue from the caustic soda extract was dried and then extracted with hot benzene.

* According to Köhler (*Die Fabrikation des Russes*, p. 13) a brown pigment known as *bistre* was formerly prepared from the soot which separated as a glossy black coating near the fire.

The solvent assumes a deep brown colour, and the extraction is soon complete. After evaporating off the benzene, a greasy, almost black, residue, was obtained, amounting to 13 % by weight of the original soot. It is sticky, and possesses the consistency of butter at the ordinary temperature, but readily softens on warming. When heated, it froths and burns with a smoky flame. For further treatment, the product was gently heated until the frothing had ceased, when it solidified on cooling to a brittle black shining mass. This was then rapidly distilled from a glass retort, and the distillate collected in two portions. The first of these, amounting to 28 grms., formed a clear brown oil, the second, amounting to 6 grms., a light reddish coloured very thick fluid, which sets at once on cooling.

The first distillate, after standing for some time at a low temperature, became semi-solid, owing to the separation of crystals, which were filtered off and purified by recrystallising several times from boiling absolute alcohol. The substance was thus obtained as a mass of interlaced, beautiful silver-white crystals, which showed a constant melting point of 59·5°. The crystals being soft, their beautiful appearance is spoiled by handling. As the yield only amounted to 0·294 grm., it was not possible to go very deeply into means of identification. The substance dissolved in carbon tetrachloride does not discolourise a dilute solution of bromine in the same solvent. It is slightly soluble in boiling alcohol, but practically insoluble in the cold. Futhermore it appears to resist nitration and sulphonation. The mean of two combustions yielded the following figures :—

C.....	84·8 %
H	14·1 %
	98·9 %

From these data it would appear probable that the substance is a saturated hydrocarbon of the paraffin series, and from its melting point and appearance it might be inferred that it is probably identical with the Heptacosane $C_{27}H_{56}$ (m.p. 59·5°) which Schwalb* isolated from bees' wax.

The filtrate from this characteristic crystalline substance showed a sp. gr. of 1·056 at 15°. It was subjected to distillation in a partial vacuum (80 mm. pressure). It began to distil at 70°, and the temperature gradually rose to 285°, when it went up suddenly to 305°. At this point the distillate began to thicken, the thermometer slowly rising to 340°, and then suddenly to 400°, when practically all had passed over, and the operation was stopped. The resulting thick, brown oil, amounting to 18·5 grms., was soluble in alcohol, ether, benzene, and glacial acetic acid.

The second part of the distillate was not sufficient in amount to allow of a more careful examination. Its solution in benzene and in alcohol shows a characteristic intense green fluorescence. From the alcoholic solution I succeeded in isolating a very small quantity of beautiful, sulphur yellow crystals.

It is evident from the behaviour of the benzene extract in distilling that it consists mainly of hydrocarbons of high boiling points. As these range in the first distillate from 170° to 400° (at 80 mm.), it would further appear probable that they represent a complex mixture.

Soot after extraction. After extracting successively with acid alkali and benzene, the soot, though much darker than before extraction, still showed a brownish-black colour, which is possibly due to the considerable amount of ash which it contains (the original sample contained 19% of a red-brown ash). In this condition it is extremely

* *Lieb. Ann.*, 235, p. 117.

inflammable, in fact it takes fire spontaneously at a temperature of about 100°, and is then difficult to extinguish. A large plate, containing the extracted soot taken from the drying stove, was seen to contain a little glowing carbon at one point, and this was extinguished. After a short time, however, it began to glow in a different part, and this being also extinguished, another part took fire, and so on, until it was nearly cold.

The following table gives the amounts of constituents estimated directly :—

Ammonium sulphate	10·7 %
Mineral matter (ash)	19·6 „
Acid constituents	10·9 „
Benzene extract (hydrocarbons) ...	13·0 „
Difference (carbon ?)	45·8 „
	100·0 „

The sample of London soot alluded to above was found to contain considerably less extractive matter than the Manchester sample. The difference was especially noticeable in the case of the benzene extract, which in the London sample only amounted to 1·3 %.

A sample of soot from Prague, for which I am indebted to Dr. F. Rademacher, showed that the products of the incomplete combustion of their lignite coal are of a very different character. The soot, which is of a brown colour, gave an aqueous extract which was neutral to litmus paper. On evaporating down the solution, calcium sulphate separated out in almost colourless crystals. The acid extract contains only traces of ammonia. Of acid constituents soluble in caustic soda I found 2 %, while the benzene extract only amounted to 0·2 %.

From the brief and incomplete account which I have brought before you, it is at least evident that the compo-

friends. While living at Wrexham, William Wilkinson and John Wilkinson were partners, but the two soon quarrelled, and instead of adopting the ordinary methods of settling difficulties between partners, William Wilkinson collected a gang of men and proceeded to break up the machinery at the Bersham ironworks. John promptly followed suit, and in a very short time the famous Bersham ironworks were wrecked, and were never worked again by the Wilkinsons. Like his brother John, William Wilkinson purchased estates in North Lancashire, and eventually settled in Cartmel parish. There he distinguished himself by indicting the highways. The parish authorities of Cartmel had maintained the highways with a view rather to economy than efficiency, with the result that in 1802, when William Wilkinson appeared on the scene, they were mere cow lanes, and were much under the statutory width. Wilkinson "indicted the roads" at the Lancaster sessions in 1804, and after some legal delay the defaulting townships were fined £2,100 for not repairing two of the roads, and Mr. Wilkinson proceeded to collect the fine at once. The legal proceedings about these and other roads lasted until Mr. Wilkinson's death in 1808, but the roads were improved. According to his nephew, Mr. Stockdale, William Wilkinson "used to say that he well knew how much he was disliked for indicting the roads in Cartmel, but that the day would come when all he had done in this respect would be approved of." Mr. Stockdale adds, and I can confirm it, that "in this he certainly predicted rightly."

As a family the Wilkinsons were distinguished above their competitors by their readiness to adopt new methods whether of their own or of others' invention. Perhaps Isaac Wilkinson was too ready to adopt new methods, and shared the fate of many pioneers, but John Wilkinson,

benefiting perhaps by his father's failures or favoured by circumstances, brought all his schemes to a profitable conclusion. Isaac's experiments with peat moss for smelting, were, as we have seen, unsuccessful, although since his time a method of smelting by this means has been devised, but John, after many experiments, was enabled to substitute common coal for charcoal in these operations, and immediately doubled the produce of his furnaces. Isaac and John Wilkinson were undoubtedly among the great men of the iron age.

Isaac Wilkinson is not noticed in the "Dictionary of National Biography," and the information given here has not hitherto been collected. Of John Wilkinson there is a life in the "Dictionary of National Biography." Stockdale's "Annales Cærmoelenses" contains some details (not altogether accurate) of the Lancashire career of the Wilkinsons. The connection of John Wilkinson with the Bersham Iron Works is the subject of an excellent monograph by Mr. A. N. Palmer, of Wrexham, which appeared in the "Transactions of the Honorable Society of Cymmrodorion," and has since been issued separately.

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XVI. Two New Aldehyde Reactions.

By W. B. RAMSDEN, B.Sc., M.B., Ch.B.

(Communicated by Mr. D. L. Chapman, M.A.).

Received February 21st. Read March 7th, 1905.

In the course of some investigations, on which I am now engaged at the suggestion of Professor Delépine, concerning the action and behaviour of formaldehyde as a preservative in food, it became necessary that some delicate and simple method of detecting the formaldehyde should be used, which is capable at the same time of being employed as a quick method of estimation. After a survey of the various ways of determining formaldehyde I am now using the cyanide method of Romjin (1) for the stronger solutions. For the weaker solutions I employ a modification of the method given by MM. Seyewetz and Gibello in the *Bulletin de la Société Chemique de Paris* (June, 1904). These authors estimate the formaldehyde by means of sodium sulphite. Starting with a 20 per cent. solution of sodium sulphite they first neutralise 20 ccs. of it with standard H_2SO_4 using a 0·2 per cent. solution of phenolphthalein as an indicator. The quantity of H_2SO_4 required for this purpose is determined once for all. In another portion of the sulphite a known volume of the formaldelhyde solution is added and a second titration with H_2SO_4 carried out. The difference in the two titrations gives a measure of the formaldehyde in the solution according to their equation

$$2Na_2SO_3 + 2HCHO + H_2SO_4 = 2(NaHSO_3HCHO) + Na_2SO_4.$$

In order to detect formaldehyde in solutions too dilute to be estimated by this method, I have modified the test

the village of Backbarrow (not Buckburrow), in the parish of Coulton, five miles from Cartmel, but the settlement must have been some years earlier, for in 1738, when Isaac Wilkinson took out his first patent, he was described as of the "parish of Coulton." This patent was for an improved box smoothing iron, its special merit being that it was cast in one piece in a mould invented for that purpose. That it was an improvement, and not a new invention, is shown by the words of the specification that the box-iron was "ground and finished in the same manner as other box-irons now in use are." Stockdale states that Isaac's business, when first he went to Backbarrow, was the manufacture of the ordinary flat smoothing iron, and having no furnace of his own, the molten metal had to be carried across the highway, from Machell's furnace close by. About 1748 Isaac Wilkinson purchased or built the iron furnace or forge at Wilson House, near Lindal, in the parish of Cartmel, and endeavoured to smelt the rich hematite iron ore with peat moss. A canal was cut into the turbary wide enough for a small boat. This boat is said by Stockdale to have been built of iron, and, if so, it was the first of that material ever constructed, and preceded by nearly 40 years the iron vessels which John Wilkinson constructed in Shropshire. Peat moss was not found suitable for smelting purposes, though the Wilkinsons tried it in its natural state, cut into peats and dried in the sun, greatly compressed and charred; so they eventually used the common wood charcoal. Stockdale says, they also made bricks from the clay which they obtained under the peat moss, and that "bricks till then had never been made in this country." This sounds incredible, unless we assume that by "this country" Stockdale means merely the Furness country.

While at Wilson House Isaac Wilkinson, describing

himself as "gentleman," took out a patent for "A new sort of cast metallick rolls for the crushing, flattening, bruising, or grinding of malt, oats, beans, or any kind of grain, and also for crushing, bruising, or grinding of sugar canes." Like the box-irons the rollers were cast in one piece. This specification was enrolled 2nd April, 1753. In the same year Isaac Wilkinson first appears in connection with the Bersham Iron Works, near Wrexham, and though he still owned property at Cartmel, his later activities were unconnected with Lancashire. In 1757, being then of "Barsham Furnace," he patented a "new machine, or kind of bellows . . . for the blowing of furnaces or forges at any distance, to be wrought or put in motion by water or fire engines." In his specification Isaac Wilkinson says that "By means of valves, regulators, cocks, or siphons alternately, the water is let out, and the air is taken in, and forced out by the water through a pipe at any distance required, so that a furnace, forge, or any other works may be blowed from any waterfall or falls, or from a fire engine, or engines, to several miles distance from the machine, by means of a pipe being fixed to the machine, to force or convey the wind through the said work. When the wind is prest out of each vessel by the water, the water is again sent out by the motion of the machine opening the valves, regulators, cocks, or siphons, and filling them again with air to make a second blast."

In the following year (1758), Isaac Wilkinson took out his fourth and last patent. This was for "a new method or invention for casting of guns or cannon, fire engines, cylinders, pipes, and sugar rolls, and other such like instruments, in dried sand, in iron boxes made for that purpose, whereby the said guns, &c., will be made and cast in a much more neat, compleat, exact, and

useful, as well as cheap and expeditious manner, than any method hitherto known and made use of." The specification gives the following particulars:—"The outside or cope of the mould or moulds in which the guns or cannon, fire engines, cylinders, pipes, and sugar rolls, or such like instruments, or any of them, is or are intended to be cast must be made of sand, mixt with a little horse or cow dung, or any other thing to make it porous. This sand is made wett and then rammed up, the patern being first put in iron boxes made for that purpose, of 2, 3, 4, 5 or any no. of parts or pieces, as the nature of the instrument to be cast requires: then the boxes are to be taken asunder into pieces and the patern taken out; then the sand in the boxes is dried in a stove and when dry it must be blacked or faced with some wett charcoal dust, or black lead or any other mixture or thing to make the sand come of or part from the metal when cast. The insides or cords of all the different instruments above mentioned are made with iron bars, either hollow and full of holes, or sollid and traced or fluted, and if the bore is large it may be made of bricks walled, and the barrs of iron or bricks are to be wraped round with ropes made of straw or hay, to take the air of, and must be then covered with a proper thickness of the said sand, and then dried and blacked, as before directed; and then the moulds are put together and the instruments cast, and bored, and turned as required." From 1652 to 1758 only 723 patents for inventions were taken out, and it is a remarkable fact that of these Isaac Wilkinson took out four.

Isaac Wilkinson was evidently a man of great enterprise, and if, as we may presume, his patents were for his own inventions, he was also a man of ingenuity. But though he was apparently prosperous for many years of his life, he became impoverished in his later years,

and eventually was entirely dependent on his two sons. Mr. Palmer says he was, about 1761 or 1762, "obliged to bring his operations at Bersham to a close," but under what circumstances he does not say. I do not find any record that he became bankrupt, and the works at Bersham were carried on by his son John. A phrase in Dr. Priestley's "Autobiography" suggests that the impoverishment of Isaac Wilkinson happened about the time that Dr. Priestley became his son-in-law, viz., on 23rd June, 1762. Writing of his wife Priestley says, "in consequence of her father becoming impoverished...in the latter part of his life, I had little fortune with her." After leaving Bersham, Isaac Wilkinson is said to have gone to Bristol. He died 31st January, 1784.

Isaac Wilkinson had three sons, John and William, mentioned later, and Henry, who died a young man, and a daughter who married Dr. Joseph Priestley, F.R.S., Unitarian Minister, whose distinction as a natural philosopher earned him a place amongst the first honorary members of our Society. Another daughter of Isaac Wilkinson is supposed to have married a Mr. Jones, and her son, who took the name of Wilkinson, carried on a long litigation with the testamentary heirs of his uncle, John Wilkinson. This T. J. Wilkinson was a resident in Manchester, and was an ordinary member of this Society. Isaac Wilkinson's eldest and most famous son, was John Wilkinson, "the father of the South Staffordshire iron trade." Born at Clifton, in Cumberland (probably the Clifton in Workington Parish) in 1728, he accompanied his father into Lancashire. He is said to have assisted his father when first he went to Backbarrow, but as he was then under ten, his assistance would not be of an important nature, and it could scarcely have interfered with his education, as it is recorded that he went to Dr.

Rotheram's academy at Kendal. In those days the Universities were closed to dissenters, but their higher education was not neglected. There were a number of academies in various parts of England, intended like the universities principally for the training of a learned ministry, but to which it was customary for the well-to-do dissenters to send their sons for a few years after the close of their school life and before entering business. One of the most famous of these academies was that kept by Dr. Caleb Rotheram at Kendal, and as John Wilkinson was one of his pupils it follows that he had had the best education then available for dissenters. I may mention that another of Dr. Rotheram's pupils, and presumably a contemporary of John Wilkinson, as they were almost of the same age, was my great-grandfather Robert Nicholson, of Liverpool, who, with his brother James, had the distinction of establishing the first alum and copperas works in Scotland. No doubt John Wilkinson was initiated into the iron trade at his father's works, but he was only twenty when he went south, and got employment at Wolverhampton. It was not long before he built a blast furnace at Bilston, and there began his career as an ironmaster. About 1756 he was assisting his father at Bersham, and in 1762 he took over his father's works, and there as elsewhere was very successful. From his first ledger at Bersham, in 1762, it appears that the Bersham Works made box-heaters, calendar rolls, malt-mill rolls, sugar rolls, pipes, shells, grenades, and guns, a list which suggests that all of the inventions of Isaac Wilkinson were actually placed on the market. It is no disparagement to John Wilkinson to say that he merely developed and improved the iron trade on similar lines to those which his father had laid down before him. Even in the manufacture of

cannon, which was one of the most profitable branches of John Wilkinson's business, he was but following his father, whose last patent (1758), like John Wilkinson's first (1774), was for methods of making and boring iron guns or cannon. Unlike his father, John Wilkinson appears to have been uniformly successful in business, and to the end of his long life he went on adding estate to estate, and forge to forge. Wherever money was to be made, John Wilkinson seems to have been. He had a most thorough belief in the value of iron, and there seemed to be nothing, from a ship to a coffin, that he did not make of that material. Most of John Wilkinson's estates were, obviously, bought for business reasons; but it may be surmised that it was sentiment that caused him to buy the estate of Castlehead, near Grange, and not far from the place where his father had laid the fortunes of the family. At Castlehead he built a house, covered the bare rock with soil, and converted it into beautiful gardens and shrubberies. In this garden it was his will that he should be buried in an iron coffin, which he had made many years before his death. He died at Hadley, his body was taken to Castlehead, and there, after two temporary interments, was buried. Appropriately enough, his tombstone was of iron. Some years after his death, his body was disinterred, and was buried for the fourth and last time in the church at Lindal. Singularly enough, one man was employed on each of these occasions, who thus helped to bury John Wilkinson four times, and to disinter him thrice.

John Wilkinson, like many of his contemporaries, found the government supply of small coins inadequate, and accordingly issued tokens of his own. He also issued his own notes, and for a time he paid his workmen in French paper money. Wilkinson, though brought up

amongst the dissenters, seems to have become a rationalist of the variety fashionable in France in the early years of the Revolution. He was generous to his workmen, and pensioned those worn out in his service. To his brother-in-law, Dr. Priestley, he was most munificent. On the occasion of the Birmingham riots, when Priestley's house, instruments, and books were destroyed, John Wilkinson, without solicitation, besides giving him £500, presented him with French bonds to the amount of £10,000, and until these should bear interest, undertook to pay him £200 a year. He left a large fortune, but the bulk of his fine estate was dissipated in litigation.

William Wilkinson, John's very much younger brother, was, it is believed, born in Lancashire. He went to a school at Nantwich which Dr. Priestley kept, a circumstance which led to Priestley making the acquaintance of the Wilkinson family, and eventually to his marriage with Miss Wilkinson. Much of Wm. Wilkinson's business life was spent abroad, and he seems to have had a cannon factory in France, in which it is not improbable that his brother John was also interested. At a later date he resided near Wrexham. "Nimrod" (C. J. Apperley) says that "setting aside his ultra-Radical principles, there was nothing against the moral conduct of the ironmaster, who, by the way, was a most entertaining companion, and quite a man of the world, in the true acceptation of that term, for he visited all countries, and he was occasionally a guest at Plasgronow...my father overlooking his political principles for the benefit of his society, and the general fund of information he possessed." Even the fact that he was suspected of supplying the French nation with cannon to be used against his own countrymen did not materially damage him in the estimation of Mr. Apperley and his

friends. While living at Wrexham, William Wilkinson and John Wilkinson were partners, but the two soon quarrelled, and instead of adopting the ordinary methods of settling difficulties between partners, William Wilkinson collected a gang of men and proceeded to break up the machinery at the Bersham ironworks. John promptly followed suit, and in a very short time the famous Bersham ironworks were wrecked, and were never worked again by the Wilkinsons. Like his brother John, William Wilkinson purchased estates in North Lancashire, and eventually settled in Cartmel parish. There he distinguished himself by indicting the highways. The parish authorities of Cartmel had maintained the highways with a view rather to economy than efficiency, with the result that in 1802, when William Wilkinson appeared on the scene, they were mere cow lanes, and were much under the statutory width. Wilkinson "indicted the roads" at the Lancaster sessions in 1804, and after some legal delay the defaulting townships were fined £2,100 for not repairing two of the roads, and Mr. Wilkinson proceeded to collect the fine at once. The legal proceedings about these and other roads lasted until Mr. Wilkinson's death in 1808, but the roads were improved. According to his nephew, Mr. Stockdale, William Wilkinson "used to say that he well knew how much he was disliked for indicting the roads in Cartmel, but that the day would come when all he had done in this respect would be approved of." Mr. Stockdale adds, and I can confirm it, that "in this he certainly predicted rightly."

As a family the Wilkinsons were distinguished above their competitors by their readiness to adopt new methods whether of their own or of others' invention. Perhaps Isaac Wilkinson was too ready to adopt new methods, and shared the fate of many pioneers, but John Wilkinson,

benefiting perhaps by his father's failures or favoured by circumstances, brought all his schemes to a profitable conclusion. Isaac's experiments with peat moss for smelting, were, as we have seen, unsuccessful, although since his time a method of smelting by this means has been devised, but John, after many experiments, was enabled to substitute common coal for charcoal in these operations, and immediately doubled the produce of his furnaces. Isaac and John Wilkinson were undoubtedly among the great men of the iron age.

Isaac Wilkinson is not noticed in the "Dictionary of National Biography," and the information given here has not hitherto been collected. Of John Wilkinson there is a life in the "Dictionary of National Biography." Stockdale's "Annales Cærmoelenses" contains some details (not altogether accurate) of the Lancashire career of the Wilkinsons. The connection of John Wilkinson with the Bersham Iron Works is the subject of an excellent monograph by Mr. A. N. Palmer, of Wrexham, which appeared in the "Transactions of the Honorable Society of Cymmrodorion," and has since been issued separately.

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XVI. Two New Aldehyde Reactions.

By W. B. RAMSDEN, B.Sc., M.B., Ch.B.

(Communicated by Mr. D. L. Chapman, M.A.).

Received February 21st. Read March 7th, 1905.

In the course of some investigations, on which I am now engaged at the suggestion of Professor Delépine, concerning the action and behaviour of formaldehyde as a preservative in food, it became necessary that some delicate and simple method of detecting the formaldehyde should be used, which is capable at the same time of being employed as a quick method of estimation. After a survey of the various ways of determining formaldehyde I am now using the cyanide method of Romjin (1) for the stronger solutions. For the weaker solutions I employ a modification of the method given by MM. Seyewetz and Gibello in the *Bulletin de la Société Chemique de Paris* (June, 1904). These authors estimate the formaldehyde by means of sodium sulphite. Starting with a 20 per cent. solution of sodium sulphite they first neutralise 20 ccs. of it with standard H_2SO_4 using a 0·2 per cent. solution of phenolphthalein as an indicator. The quantity of H_2SO_4 required for this purpose is determined once for all. In another portion of the sulphite a known volume of the formaldelhyde solution is added and a second titration with H_2SO_4 carried out. The difference in the two titrations gives a measure of the formaldehyde in the solution according to their equation

$$2Na_2SO_3 + 2HCHO + H_2SO_4 = 2(NaHSO_3HCHO) + Na_2SO_4.$$

In order to detect formaldehyde in solutions too dilute to be estimated by this method, I have modified the test

by starting with sodium metabisulphite (thus carrying out a suggestion of Mr. Thos. Tyrer made publicly some time ago). A test solution is made as follows: 50 grammes of sodium metabisulphite are dissolved in 100 ccs. of water and filtered. To this strongly acid solution 50 % NaOH is added until nearly neutral. 2 ccs. of the solution are now taken, made up to 50 ccs. with distilled water and 1 cc. of phenolpthalein solution added, and the whole put into a Nessler glass. Decinormal Na_2CO_3 or NaOH is added until the phenolphthalein indicates a very slight alkalinity. The original solution is then neutralised with the requisite amount of Na_2CO_3 or NaOH, and then allowed to stand for two days in a stoppered bottle. 2 ccs. of this solution added to 48 ccs. of distilled water and 1 cc. of phenolphthalein should only give the faintest possible pink colouration.

To test for formaldehyde 50 ccs. of the solution (neutral) supposed to contain formaldehyde are taken in a Nessler glass, and 2 ccs. of the reagent and 1 cc. phenolphthalein added. A pink to red colour is produced if formaldehyde is present. A control with distilled water should always be made.

The delicacy of the test with formaldehyde is about 4 parts per million.

As might be expected, other aldehydes, *e.g.* acetaldehyde, give the reaction, but not with the same dilution as formaldehyde.

It is important that care should be taken to use aldehyde—free alcohol in the preparation of the phenolphthalein solution, as some samples contain aldehyde in appreciable quantity. The reaction may be expressed by the equation

$$Na_2SO_3 + HCHO + H_2O = (NaHSO_3HCHO) + NaOH.$$

Coloured or turbid solutions must first be distilled.

In a search for a reaction capable of detecting quantities less than the lower limit of the above reaction, I found that the ordinary Nessler solution reacted with formaldehyde.

(2) *With Nessler Solution.*

If to a solution of formaldehyde in a Nessler glass the usual quantity of Nessler reagent (2 ccs.) is added a reaction takes place dependent on the strength of the formaldehyde solution. If the solution is fairly strong an immediate blackish-brown precipitate is produced due to the reduction of the Nessler solution.

In weaker solutions the reaction proceeds more slowly, a canary-yellow colouration being produced at first, then the solution becomes slightly opalescent and of a greenish-yellow colour and finally darkens, and on allowing to stand a precipitate falls to the bottom, the colour of which depends on the concentration of the formaldehyde solution.

In a dilution of 1 part HCHO in 1,000,000 of water the change from the canary-yellow to the dark brown takes about one hour to complete. The reaction is quite apparent at a dilution of 1 part HCHO in 2,000,000, and the suspended matter settles down to the bottom in 24 hours.

This reaction is therefore of great delicacy, and can be used for detecting minute traces of HCHO.

(1) *Zeits. f. analyt. Chemie*, vol. 36, pp. 18-24, 1897.

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XVII. The Stem and Branches of *Lepidodendron selaginoides.*

By F. E. WEISS, D.Sc.,

AND

JAMES LOMAX.

Received for publication June 6th, 1905.

In the discussions which have taken place on the relationship between the two genera Sigillaria and Lepidodendron, the two plant-remains known as *Sigillaria vascularis* (Binney) and *Lepidodendron selaginoides* (Sternb.) have figured very prominently. On the one hand Renault, following Brongniart's lead relegated such stems as those of *Sigillaria vascularis*, which showed a ring of secondary wood (*c.p. fig.* 3 of *Plate*) to the Sigillariæ which he looked upon as allied to the Phanerogams and particularly to the Gymnosperms while the *Lepidodendra* were according to him devoid of secondary thickening and connected with the recent Lycopodiaceæ.

Binney ('62, '65, '72, '75), on the other hand, in a series of papers in which he described a large number of specimens of *Sigillaria vascularis* and of *Lepidodendron selaginoides* or *Lepidodendron vasculare* as he preferred to call it, brought forward very considerable evidence in favour of regarding the two as representing merely different stages in the development of the same plant. This conclusion he based upon evidence both from the external and also from the internal structure of the plant. For while on the one hand some specimens have a ribbed and furrowed

bark, others with rhomboidal markings have the same internal structure, so that the ribbed condition must be looked upon as an older semi-decorticated stem from which the leaf cushions have disappeared. Not only did Binney find these two conditions of the stem constantly associated together, but he could trace them "gradually passing from one into the other."* "These facts," he says, "when taken in connection with the similarity in structure in the central axis, the internal radiating cylinder, the space filled with lax cellular tissue between the latter and the outer radiating cylinder diverging from circular openings, clearly prove that the smaller specimen [*Lepidodendron selaginoides*] is but the branch of the older stem" [*Sigillaria vascularis*].

Williamson ('78 and '81) in parts IX. and XI. of his "Organization of the Fossil Plants of the Coal Measures," supports Binney's contention and this view of the identity of the two forms is accepted after critical examination by Solms-Laubach ('87) and by Hovelacque ('92) in his most detailed and careful examination of this plant.

There seems, therefore, to have been a very considerable amount of agreement as to the identity of these plants, based upon a comparison of their internal and external structure, but as far as we know, no evidence of actual continuity was brought forward. It is true Binney speaks of a gradual passing of large ribbed specimens into smaller ones with rhomboidal scars; but from the context of the passage we gather that he meant that all intermediate stages were to be found between the two forms.

In the specimen before us now, however, we have such actual continuity of structure. For it represents a piece of a large ribbed stem, about 6½ inches in height, which

* See Binney, ('65), p. 490.

shows the structure of Binney's original *Sigillaria vascularis* giving off branches which possess the organisation of *Lepidodendron selaginoides.* The specimen was discovered by Mr. James Lomax in a nodule from the Fieldhouse Colliery (Halifax Hard Bed) near Huddersfield. The nodule was about 1 foot 6 inches in length by 9 inches broad and 3 to 4 inches in thickness. The depressed scar of the axis as shown in *fig.* 2 of the *Plate* was visible on the outside of the nodule after cleaning, while a similar one on the other side was laid bare after a portion of the nodule was removed. Externally, as seen in *fig.* 2, the stem shows a ribbed and fluted aspect as if it might have belonged to a *Sigillaria* of the *Rhytidolepis* type from which the leaf cushions had disappeared. But Binney has already shown (as stated above) that stems with this aspect are found continually associated with branches having rhomboidal markings of typical lepidodendroid character. Like the specimen figured by Binney ('75) (plate XIX., fig. 2), it shows the scar of a lateral branch, but the latter, instead of forming a prominent protuberance, is represented by an oval depression at one end of which is the remnant of the lateral branch, which shows on its surface somewhat indistinctly rhomboidal leaf cushions. It is probable that we have here very much the same structure as that described by Solms-Laubach* as typical for lepidodendroid branching when the branches are of unequal thickness. Where as in *Knorriæ* this happens commonly, "the thinner lateral branch will often impede the further growth in thickness of the main stem and then the base of the side branch is seen to be embedded in a lateral groove which forms on the stem."

In our specimen the lateral shoot is found at one end of the depression, which becomes shallower towards the

*Solms-Laubach ('87), p. 205.

base, and thus the scar resembles to a certain extent those of *Bothrodendron.* It is interesting to find on comparing our specimen with that figured by Binney, that the origin of a branch in the same plant may be represented in the one case by a prominence, in the other by a depression. The same differences are found in ulodendroid and halonial branches of other lepidodendroid plants. In our specimen there appear to have been two rows of branches, on opposite sides of the stem, an arrangement which seems to have been common in the Lepidodendraceæ.

It is a point of particular interest that while sections of the main axis show it to have possessed a considerable amount of secondary wood evenly distributed around the central axis, the lateral branches have the structure of small branches of *Lepidodendron selaginoides*, without secondary growth (see *fig.* 1 of the *Plate*). Thus, as first suggested by Binney, the *Sigillaria vascularis* was only an older stage of *Lepidodendron vasculare.* In the latter form the secondary wood, when developed, often presents a crescent-shaped appearance, or, if continuous all round, the primary wood is developed more strongly on one side than the other. This is not usually seen in the stems originally named *Sigillaria vascularis*, and it would seem quite probable that these represent the upright main stem, while the lateral branches showed an eccentric development of secondary wood, such as is met with in the lateral branches of some of our phanerogamic trees of to-day. If the main stem gave off, as it seems, lateral branches of slighter girth, while the branches themselves divided dichotomously, the habit of *Lepidodendron selaginoides* must have resembled very nearly the reconstruction of *Lepidodendron elegans*, figured by Dr. Scott (:00).*

As will be seen from the longitudinal section repre-

* "Studies in Fossil Botany," fig. 47, p. 117.

sented in *fig.* 1, the lateral branches from the main stem did not come off quite horizontally but were directed obliquely upwards. Thus the central cylinder of the lateral branch, which is cut obliquely, is found in *fig.* 1, below the horizontal crack which traverses the main stem while on the outside of the stem it will be seen as a little central projection well above the horizontal fissure. The oblique upward direction of the branch prevents the details of the structure from being distinctly visible, but *fig.* 4, which is taken from a transverse section of a similar stem from the Cash Collection in the Manchester Museum (Cabinet number Q 384) shows the details of structure very clearly. The two axes are still organically connected, but while the left hand stem has a considerable amount of secondary wood the right hand branch has little or no such thickening. At the same time, judging from the two axes, the branching seems to have been a little less unequal than in the above specimen.

A similar specimen to *fig.* 4 but showing branches cut transversely on either side of the main axis, is in the possession of Dr. D. H. Scott. Though it is very likely that unequal branching, such as described above, is generally accompanied by such a difference in the vascular tissues, as is seen in these specimens, yet it is not certain that this difference was always present. For Williamson ('95)* mentions a case of "unequal dichotomy, but of the type in which, though one of the two resultant branches is very much smaller than the other, there is no difference in the details of their organization." This dichotomy he stated occurred in the largest section of the *Selaginoides* type which he had yet discovered, so that one would infer that both must have shown a very considerable amount of

*Williamson, ('95), p. 4.

secondary growth, in which case the lateral branch would of course approximate to the main stem in structure.

But in the two specimens before us, the structure in the main stem and the lateral branch differs considerably in the amount of secondary wood formed, while the continuity of tissue is proof of the correctness of Binney and Williamson's views as to the identity of the plant to which these two kinds of axes belonged.

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EXPLANATION OF PLATE.

Fig. 1. A tangential section of stem represented in fig. 2, showing the unthickened Lepidodendron axis on its way out to the oval depression (note that the axis stands in a somewhat lower position than it occupies at the surface, see fig. 2).

„ 2. A photograph by Mr. Lomax of the exterior of a decorticated (ribbed) stem (*Sigillaria vascularis* of Binney), showing oval depression from which the lepidodendroid branch was given off.

„ 3. Enlarged view of section of stem of *Lepidodendron selaginoides*, showing primary and secondary wood.

„ 4. A transverse section of a main axis and lateral branch organically connected, the former showing a considerable amount of secondary wood (W_2) typical of *Sigillaria vascularis* (Binney), while the latter is a typical section of *Lepidodendron selaginoides.*

Fig. 1.

Fig. 2.

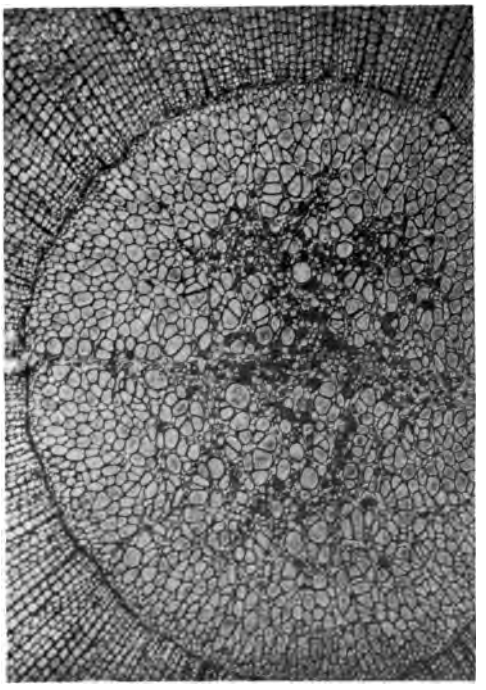

Fig. 3.

W$_2$.

Fig. 4.

PROCEEDINGS

OF

THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

Ordinary Meeting, October 4th, 1904.

Professor W. Boyd Dawkins, D.Sc., F.R.S., President, in the Chair.

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Mr. C. L. BARNES, M.A., exhibited a photograph of a little-known etching of Dr. John Dalton, drawn by a local engraver, J. Stephenson, rather more than sixty years ago.

Mr. CHARLES BAILEY, M.Sc., F.L.S., communicated the following "**Note on *Sisymbrium strictissimum*, Linn., at Heaton Mersey, for the last fifteen years (1890—1904).**"

The genus *Sisymbrium*, apart from the aboriginal species admitted in the British flora, is manifesting a predilection for Lancashire and Cheshire, if we may judge from its attempts at colonisation, in recent years, by one or other of its species. *S. polyceratium*, L., has long been a constituent of the Cheshire flora at Birkenhead and Egremont; *S. pannonicum*, Jacq., recently noticed in the Society's *Memoirs* (Vol. 47, Part I., 1902), is naturalised at St. Anne's-on-the-Sea, Fleetwood, Preston, Crosby, Blundellsands, and elsewhere; and now a third species, *S. strictissimum*, L., has to be chronicled as having secured a foothold near Manchester.

Some examples of the last-named plant, from Heaton Mersey, were sent me for naming, six weeks ago, by an ardent Stockport botanist, Mr. Jas. E. McDonald, who is doing excellent work in tracing the life-histories of some of our common British plants, and whose papers on *Ranunculus Ficaria* (*Naturalists' Journal*, Nov., 1902, p. 187), and *Adoxa Moschatellina* (*Nature Study*, Sept., 1904, p. 189), are admirable types of painstaking investigation.

Sisymbrium strictissimum occurs on the Lancashire side of the Mersey, in the grounds surrounding the works of Messrs. Melland and Coward, Ltd., manufacturers, bleachers, and dyers, of Vale Road, Heaton Mersey; this firm, through their Mr. E. A. Russell, has been most obliging in granting ready access to its grounds.

Mr. McDonald first noticed it at this station five or six years ago, and it has not only held its own amidst the other vegetation, but has steadily increased its area. The plant was first observed many years ago as growing outside the boundaries of the bleach-works, on the Stockport side, but last summer Mr. McDonald noticed it from the opposite bank of the Mersey, growing on a waste heap on the west side of the bleach-works, its rich yellow corymbose flowering spikes making it sufficiently conspicuous in the mass. Mr. McDonald tells me that several Stockport botanists, besides himself, without being able to ascertain its name, have had the plant under their observation for many years, and have gathered

it in the ground beyond the bleach-works; two of them gathered it in this station ten or twelve years ago; and a third has known it in the same spot for the last fifteen years. Its persistence may therefore be accepted as established.

The open ground fronting the river to the west of the bleach-works is where the plant is most at home, and this may be the oldest colony of the plant, although the dates named in the preceding paragraph apply to plants gathered in the station to the east.

The plant grows in clumps amongst the grass and other herbage for about fifty or sixty yards on the Stockport side of the works, as well as on the waste heap at the back of the works. There are about twenty clumps in all, a dozen of which occur on the western side, and eight on the eastern side; two of the larger clumps would cover areas of about six square yards each. The plant grows to a height of two or three feet, or even more. Its associates are *Artemisia vulgaris*, *Cnicus arvensis*, *Urtica dioica*, and species of *Tragopogon* and *Scrophularia*, all of them plants of a character suggesting strong competition in its struggle for existence.

The following are some of Mr. McDonald's notes of his examinations of the numerous seedlings which occur. In the first season the primary stem grows from three to eight inches in height, but most of this decays with the advance of winter. The second year's growths usually consist of two branches, each of which springs from the axils of the decayed cotyledons; if the branches are more than two they appear to arise from adventitious buds, formed just below the cotyledons. By the end of the second season the roots are vigorous, being both thick and long, and a cluster of as many as a score of buds may have been formed, each of which is capable of developing a new stem.

It is not possible with any degree of certainty to indicate the source of the plant. A manufacturing and industrial concern necessarily brings many foreign seeds, in the materials employed, and in the food and litter required for horses. Beans will come

from Egypt and elsewhere, corn and materials from all parts of the world. Doubtless to some such origin its appearance at Heaton Mersey must be attributed.

The headquarters of *Sisymbrium strictissimum* are in continental Europe. I have examples in my herbarium from the following localities, viz. :—

Huez-en-Oisans, Isère, France .....26th August, 1882, Coll. P. Faure et T. Chaboisseau.
Villette, La Tarentaise, France.....19th September, 1859, E. Perrier.
Saint-Jullien, Savoie, France.....10th July and 10th August, 1856, E. Didier.
Holzminden, Brunswick, Germany .. 25th June, 1871, Dr. Menze.
On the Elbe, Dresden, Saxony.....(Reichenbach Exs. 685).
" " " .....30th June and 12th August, 1885, Lodny.
Neunmühlen, Znaim, Moravia.....20th June, 1880, A. Oborny.
Mt. Leopoldsberg, Vienna, Austria ...July, 1880, Dr. E. de Halácsy.
" " " ...August, 1887, C. Heinrich.
Eichhogel, " " ...Trichoda.
Mt. Anningen, Mödling " ...(Fl. exs. Aust. Hung., 2887) Vieshapper.
Lienz, Tyrol .....June, 1870, Gander.
Gösling, bei Graz, Styria .....30th July, 1885, E. Preissmann.
Schwabenberge, bei Ofen, Hungary...13th June, 1879, W. Steinitz.
Buda, Hungary .....May-June, 1879, L. Richter.
St. Rémy, Aosta, Piedmont .....July, 1881, Carron.
Bormio, North Italy .....14th and 29th July, 1896, M. Longa.

And it also occurs in Switzerland, Russia, the Rhine Provinces, Bavaria, Bohemia Salzburg, Carinthia, and the Balkan States.

So far as herbarium examples furnish the means of comparison, it would appear that the Heaton Mersey plants are more vigorous and ample in their growth. The chief difference is seen in the length of the siliques or long pods, which are from an inch to an inch and a quarter long, or half the normal length of continental examples. As will be seen from the specimens now submitted to the members, the fruiting heads are conspicuously flat-topped. The seeds are produced in profusion and, from the mounted seedlings before the meeting, may be considered fertile; they are minute and readily transported by the wind. Now that attention is called to the existence of the species in our flora, its occurrence may be looked for along the course of the river, and elsewhere.

Sir WILLIAM BAILEY then occupied the Chair, whilst the PRESIDENT read a paper entitled "**Note on the Effect of Relaxation of Pressure in causing Folds at the Bottom of Valleys,**" in which he called attention to a new cause of folding of the rock other than that which has been long recognised by geologists as ultimately due to the folding of the outer layers of the earth as they follow the contracting nucleus. The deep cuts made through valleys to make watertight barriers in the construction of reservoirs, revealed the fact that the bottom of the valleys, wherever it was formed of shales and thin sandstones, was more or less folded and contorted. These folds and contortions caused the shales to let the water through with more or less freedom, and he had been called in repeatedly to advise as to how far it was necessary to carry the puddle trenches down below the valley bottoms. He found, as a matter of experience, that these folds were superficial, and if the sinking were made to a sufficient depth below the bottom of the valley, they disappeared altogether. It was therefore obvious that they were not due to deep-seated movements of compression, resulting from the contraction of the earth. They are due to the relaxation of pressure caused by the removal of the rock by denudation from the area of the valley, and are analogous in every particular to "the creep" in coal workings, caused by the excavation of coal, by which the surrounding strata crush down into the area of relaxed

EXPLANATION OF PLATE.

Fig. 1. A tangential section of stem represented in fig. 2, showing the unthickened Lepidodendron axis on its way out to the oval depression (note that the axis stands in a somewhat lower position than it occupies at the surface, see fig. 2).

„ 2. A photograph by Mr. Lomax of the exterior of a decorticated (ribbed) stem (*Sigillaria vascularis* of Binney), showing oval depression from which the lepidodendroid branch was given off.

„ 3. Enlarged view of section of stem of *Lepidodendron selaginoides*, showing primary and secondary wood.

„ 4. A transverse section of a main axis and lateral branch organically connected, the former showing a considerable amount of secondary wood (W_2) typical of *Sigillaria vascularis* (Binney), while the latter is a typical section of *Lepidodendron selaginoides.*

Fig. 1.

Fig. 2.

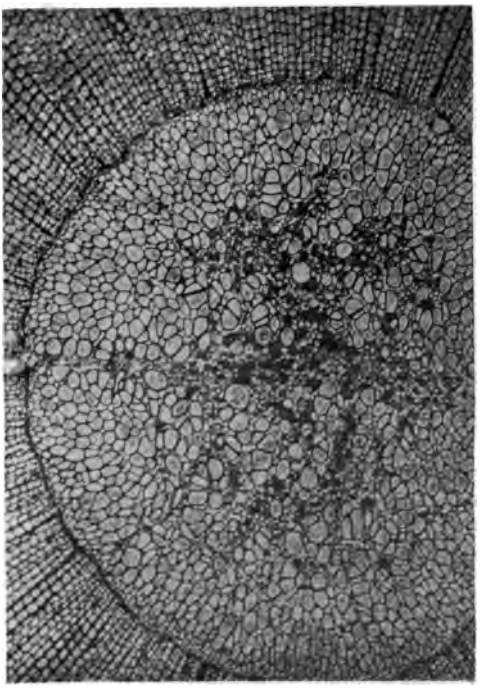

Fig. 3.

W_2.

Fig. 4.

PROCEEDINGS

OF

THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

Ordinary Meeting, October 4th, 1904.

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Non Mau

Blackbacked, and the Glaucous Gulls which have been kindly lent to me by Mr. Herbert Massey, of this city, and I see no reason why this type like the blue type should not occur in all the species. This change of colours in the eggs of Gulls may be of interest, and will probably show that since there is no necessity for protective coloration that they are subject to remarkable variations from the type.

The *Sandwich Tern* is another exception to the theory of protective coloration. The bird itself is very prominent, and deposits its eggs often upon the bare sand or shingle. This species shews little anxiety with regard to its eggs, and often breaks them in its precipitate flight on being disturbed in its breeding haunts. The eggs vary in colour from a pure white to the darker shades of brown, being invariably spotted and blotched, whilst the brown eggs to a certain extent partake of the colour of the sand, the lighter coloured ones are nearly always conspicuous, as is also the young of the species. The eggs are occasionally, though rarely, deposited in a well formed nest, and it would appear from its carelessness in the selection of its breeding site and from the light colour of its eggs that a factor other than protective coloration has influenced its breeding habits.

The *Sandwich Tern* and the *Blackheaded Gull* often breed together in perfect harmony, and being very pugnacious, protect themselves by uniting in force to drive off their enemies.

The *Little Tern* usually deposits upon the sea beech its eggs, which greatly resemble the sand or shingle upon which they are laid. The eggs are like small editions of those of the Sandwich Tern, but generally inclined to the darker tints. The lighter are sometimes difficult to distinguish from the broken shells with which the nest is often surrounded. I have noted that in a wind-storm many of the eggs are destroyed possibly by the bird in its endeavour to rescue them from being buried in the drifting sand. This species is weak and defenceless, and always easily detected in its breeding haunts, and except for the colour of its eggs has nothing that would serve as a protection from its

enemies, and it is consequently a declining species as far as this country is concerned.

The *Oyster Catcher* is another bird that always attracts our attention on the sea shore, and its eggs are very difficult to discover, as they resemble the colour of the ground on which they are deposited. I have noted in connection with this species that its eggs are often of a dark and a light variety, and I may mention that on more than one occasion the dark ones have been deposited on the darker mud of the marsh, whereas the lighter eggs have been deposited on the sand which they very closely resemble.

The *Ring Plover*, another familiar shore bird, also deposits its eggs amongst the sand or shingle, where, owing to their resemblance to the site of the nest, they are very difficult to find.

The *Oyster Catcher* and *Ring Plover* must rely to a great extent for protection on their watchfulness, as it is difficult to get within gun-shot of them.

Most birds laying white eggs deposit them in holes and dark places, whilst dark coloured eggs are seldom, if ever, found in such situations. The coloration of birds laying white eggs is usually brilliant, whereas birds laying dark eggs are usually of sober plumage. The Snipes and Plovers lay eggs resembling the earth upon which they are deposited. The *Snowy Owl* and frequently the *Eagle Owl* lay their white eggs on the ground; both are birds well able to protect themselves from danger, so that there is no necessity for them to hide their eggs from view as do nearly all other owls.

In conclusion, I would point out that the prevailing colouring matter on eggs is for the most part of brown in various shades with a tendency to reddish, and a great many species of eggs frequently show a red variety. In the case of the *Guillemot* it is generally supposed that the birds, having had few enemies, the coloration of the eggs is not subject to any natural restraint and they have developed extraordinary variations.

Mr. ELLISON also exhibited, as lantern slides, a number of excellent photographs of the nests and eggs of some of the above-mentioned birds as seen in their native haunts.

Mr. MORRIS-AIREY's paper on **"The Determination of Wave-lengths in the extreme Ultra-violet part of the Spectrum,"** was reserved for the next meeting on November 29th.

Ordinary Meeting, November 29th, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. The following were among the recent accessions to the Society's Library:—"*Flora Capensis*"...vol. iv. Sect. 2, pt. iii. By Sir W. T. Thistleton-Dyer (8vo., London, 1904), purchased; "*Obras sobre Mathematica*," do dr. F. Gomez Teixeira ... (fol., Coimbra, 1904), presented by the Académie Polytechnique de Porto; "*The Anthracitation of Coal*," by D. Burns (8vo., London, 1904), presented by the N. of England Institute of Mining and Mechanical Engineers; and "*Wind Charts for the South Atlantic Ocean*" (obl. fol., London, [1904]), presented by the Meteorological Office.

Mr. H. MORRIS-AIREY, M.Sc., read a paper entitled, **"Determination of Wave-lengths in the extreme Ultra-violet part of the Spectrum."**

Ordinary Meeting, December 13th, 1904.

Mr. W. H. JOHNSON, B.Sc., in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The following letter from Dr. Charles Davison, of Birmingham, on British Earthquakes, was read by the Secretary:—

Dear Sir,

During the last 16 years, I have been engaged in studying the earthquakes of this country, the results of my work being contained in papers published in the *Quarterly Journal of the Geological Society*, and the *Geological Magazine*, and in my report on the "Hereford Earthquake of December 17, 1896." I propose now to carry the work backwards, so as to prepare as complete a history of British earthquakes as may be possible at the present day. To do this at all satisfactorily is, of course, beyond the powers of one man. It requires access to the files of the local newspapers. Records of past shocks may be preserved in private journals, and not a few are to be found in the pages of county and parish histories or local magazines. These sources are for the most part inaccessible to all but their owners, and it is therefore only by the kindly aid of others that the necessary materials can be procured. If any members of the Manchester Literary and Philosophical Society should be able and willing to contribute records, either from the sources mentioned above, or from their own recollections, of earthquakes felt in any part of the country, but especially in Lancashire, such help would, I need hardly say, be of the very greatest service in my work.

As a seismic district, Lancashire is one of the most important in the British Isles, no English county having been disturbed so often, and only three counties in Scotland more frequently, during the last hundred years. The dates on which recorded

earthquakes occurred since the beginning of the 19th century are as follows:—June 1, 1801; March 17, 1816; November 9, 1817; October 31, 1818; March 23, 1827; June 11, 1833; August 25, 1835; June 11 and 12, 1839; June 21, 1842; March 10 and 17, 1843; December 3, 1845; November 9, 1852; October 6, 1863; September 26, 1864; January 15, 27 and 28, and February 15, 1865; February 22 and 23, 1867; October 30 and November 22, 1868; March 14, 15 (2 shocks), 25, and 28, 1869; February 23, March 17, 18, and 22, 1871; July 16, 1873; November 14, 1884; June 30, 1885; January 5, 1886; December 1, 1887; February 10, 1889; November 2, 1893; December 17, 1896; July 9, 1901 (2 shocks); March 24 and June 19, 1903; and July 3, 1904. Thus, altogether, 46 earthquakes have been felt in Lancashire during little more than a century. Many of them belong to earthquake centres situated in other counties. The earthquakes of 1863, 1868 (October 30), and 1896, originated in Herefordshire; that of 1852 beneath the Irish Sea; the earthquake of 1893 in Pembrokeshire; and that of June 19, 1903, in Carnarvonshire; while the earthquakes of March 24, 1903, and 1904, were due to almost simultaneous impulses in two Derbyshire foci, one near Ashbourne, the other near Wirksworth. There remain, however, a large number which originated in centres situated within or close to the limits of the county, among the most interesting being those of March 17, 1843, March 15, 1869, and March 17, 1871.

It is possible that some of the above disturbances may not have been true earthquakes. In all mining districts, shocks occur from time to time, like those felt in the district round Pendleton on February 27, 1899, and April 7, 1900, which are in all probability connected more or less closely with mining operations. In some cases, they may be due to rock-falls from the roof of the workings, but generally, I believe, to small fault-slips when the rock in the neighbourhood of a fault has been deprived of its support by the withdrawal of the coal, etc.

Of the earthquakes which have occurred since 1899, I have now, I think, sufficient descriptions. With these exceptions,

notes about any of these shocks would be most useful, but I should be especially glad to receive accounts of those of March 17, 1843, November 9, 1852, October 6, 1863, October 30, 1868, March 15, 1869, March 17, 1871, and February 10, 1889. Notices of the local shocks in mining districts would be of much interest, as also would be records of the effects of the great Lisbon earthquake of 1755, if any such are known to have been observed.

The points on which I desire most to obtain information are indicated in the appended series of questions. I may add that I shall be glad to send printed copies of these questions to any Members of the Society or others who may be able and willing to give, to however slight an extent, the valuable assistance suggested in this letter.

QUESTIONS.

1. Place of observation.
2. Condition of the observer when the earthquake began: (*a*) indoors or outside, (*b*) awake or asleep.
3. Time of occurrence.
4. (*a*) Nature of the shock. (*b*) Did it consist of two distinct parts separated by a brief interval of rest and quiet? (*c*) If so, which part was the stronger, and how long was the interval between them?
5. Was the shock strong enough: (*a*) to make doors, windows, etc., rattle; (*b*) to cause the observer's seat to be perceptibly raised or moved; (*c*) to make pictures, chandeliers, etc., swing? (*d*) to overthrow ornaments, vases, etc.; (*e*) to throw down chimneys, or crack the walls of buildings?
6. Was any unusual sound heard at the time, and what did it resemble?
7. Were any slight shocks felt before or after the principal earthquake; if so, at what times, etc.

Mr. CHARLES OLDHAM communicated the following "**Note on the Dissemination of Seeds by Birds.**"

The opinion expressed by Mr. F. Nicholson, F.Z.S., at a recent meeting of the Society that birds rarely act as disseminators of seeds, by voiding them in their excrement, is not in accord with the experience ot many field naturalists. Nearly fifty years ago Darwin proved (*Origin of Species*, chap. xii.) that certain seeds extracted from the excrement of small birds germinated, as did others from the ejected pellets and the excrement of carnivorous and piscivorous birds. The evidence of Wallace and other observers may be cited to the same effect. It is perhaps worth mentioning in this connection that in Mid-Cheshire during the spell of hard weather at the end of November, an examination of the excrement of various birds showed that entire and apparently uninjured seeds are voided constantly. Redwings, fieldfares, and other thrushes were compelled during the frost to subsist largely upon hedgerow fruit, and entire seeds of the wild rose (*Rosa*) and hawthorn (*Cratægus*), among others might have been collected from their droppings by thousands. From the excrement of smaller birds I obtained many undigested seeds of the bramble (*Rubus*). I have often noticed entire seeds in the excrement of wild ducks, birds of sustained and powerful flight.

Mr. Oldham also exhibited some of the seeds mentioned in his note.

Dr. W. E. HOYLE, F.R.S.E., read the following letter, containing an account of an appearance of the Sea Serpent, which he had received from Mr. C. Howard Tripp, of New Zealand :—

September 16th, 1904.

About 6 years ago I was getting into the 8 a.m. Monday train at Timaru, New Zealand, when, what at first appeared to be a sooty albatross, seemed to drop on to the sea with a great splash about 500 yards from me. The sea was calm, but the sun was slightly in my eyes. However, as I had never seen an albatross come down in that way before and disappear below the surface, I watched the spot, and soon saw it come up again, and then saw it was not an albatross, but the tail of some fish, as it had a long, thin body attached to it. It came down again with a great splash, disappeared and went up again, and then disappeared entirely. I should say that the body attached to the

tail was about eighteen inches in diameter by the tail, and thickened to two feet or more about 12 to 16 feet from the tail, which was about the height it came up above the sea. I was naturally immensely surprised and struck with what I saw, so continued to watch, and a few seconds after the final disappearance of the tail I saw a most distinct serpent's head come out of the water about 50 yards from where the tail had disappeared; it came out with about 10 or 15 feet of body all of a uniform thickness of about 3 to 4 feet, seemed to look round, and then disappeared, and I never saw it again. Where I saw it was shoal water of about three fathoms and on the edge of a dolerite reef. It might have been a bottle-nosed whale, and I might have been deceived by the sun being slightly in my eyes, but my first impression at the time was, and still is, that it was a serpent-like creature. Subsequently I heard that the serpent had about two days previously been seen about 10 miles south of Timaru, and the movements I saw corresponded with a description I had read of a serpent being seen off the coast of the North Island of N.Z. about a year previously.

Dr. HOYLE afterwards suggested that what Mr. Tripp really saw may have been a Cetacean. Most sea-serpent stories, he said, on close investigation, resolved themselves into something more familiar. Speaking generally, they could be classed under several heads, such as a shoal of porpoises, a flight of birds, a large squid, or other previously known object.

Dr. C. H. LEES exhibited and described a series of micro-photographs of steel wire in different stages of the drawing process taken by the National Physical Laboratory from steel wires used by Dr. J. R. Ashworth in his recent work on the magnetic and other physical properties of drawn steels. The longitudinal arrangement and extension of the particles becomes very marked at a certain stage of the drawing process, and at that point the capability of the steel of being magnetised also increases considerably.

Mr. HENRY SIDEBOTTOM read a paper, entitled, **"The Foraminifera from the Coast of the Island of Delos." Pt. II.**

General Meeting, January 10th, 1905.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

Mr. GEOFFREY DUFFIELD, B.A., B.Sc., of Adelaide, South Australia, Research Fellow in the University of Manchester was elected an ordinary member of the Society.

Ordinary Meeting, January 10th, 1905.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. The following were among the recent accessions to the Society's Library:—"*On Recent Contributions to our Knowledge of the Floor of the North Atlantic Ocean*," by Sir J. Murray and R. E. Peake (8vo., London, 1904), presented by the Royal Geographical Society; "*Le Opere di Galileo Galilei*," vol. 14 (4to., Firenze, 1904), presented by the Italian Government; "*London Fog Enquiry, 1901-02: Report to the Meteorological Council*," by Capt. A. Carpenter (4to., London, 1903), and "*London Fogs: Report of the Meteorological Council*" (4to., London, 1904), presented by the Meteorological Office; "*Codex diplomaticus Lusatiæ superioris II.*, Bd. ii., Hft. 5., von Prof. R. Jecht (8vo., Görlitz, 1904), presented by the Oberlausitzische Gesellschaft der Wissenschaften; "*Catalogue of Canadian Birds*," Pt. iii., by J. Macoun (8vo., Ottawa, 1904), presented by the Geological Survey of Canada; "*Subject List of Works on the Fine and Graphic Arts in the Library of the Patent Office*" (16mo., London, 1904), presented by the Patent Office; "*The State of Missouri*," by W. Williams (4to., [Columbia], 1904), presented by the Missouri World's Fair Commission.

Mr. R. L. TAYLOR, F.C.S., exhibited an interesting piece of marble which contained minute crystals of sulphur.

Mr. A. D. DARBISHIRE, M.A., B.Sc., read a paper entitled, **"On the Supposed Antagonism of Mendelian to Biometric Theories of Heredity."**

Mr. DARBISHIRE also exhibited the results of a hybridization experiment with mice, illustrating Mendelian phenomena of heredity.

Messrs. C. H. BURGESS, M.Sc., and D. L. CHAPMAN, M.A., communicated a paper, entitled, **"The cause of the Period of Chemical Induction,"** which was postponed to the next meeting on January 24th.

Ordinary Meeting, January 24th, 1905.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The PRESIDENT announced that the Council had awarded the Wilde Medal to Professor Charles Lapworth, LL.D., F.R.S., of Birmingham University; that the Wilde Lecture would be undertaken by Dr. D. H. Scott, F.R.S., of Kew; and that the presentation of the Medal and the delivery of the Lecture would take place on February 28th.

Mr. H. MORRIS-AIREY, M.Sc., read a paper entitled **"On the Rigidity of Gelatine."**

Messrs. C. H. BURGESS, M.Sc., and D. L. CHAPMAN, M.A., communicated the following paper on **"The Cause of the Period of Chemical Induction."**

The induction period which precedes the regular combination of a mixture of hydrogen and chlorine exposed to light has

occupied the attention of numerous chemists during the last fifty years. It has been ascribed to various causes, notably to the preliminary formation of an unstable intermediate compound. The authors have succeeded in showing that the induction period in question is due to the presence of minute traces of impurities contained in the chlorine, and in the aqueous solution in contact with it. All of the impurities examined which prevent the combination of hydrogen and chlorine have been proved to be substances capable of reacting with chlorine, for example, ammonia and sulphur dioxide. These substances react with chlorine in the presence of light and are gradually destroyed, the action between the hydrogen and chlorine being almost entirely prevented until their removal is complete. The elimination of these poisoning substances in presence of chlorine can also be effected by means of heat. In some cases it even occurs on long standing at the temperature of the laboratory.

Contrary to what has been previously assumed, pure chlorine is active towards hydrogen, the pure gas from the electrolytic cell only becoming inactive after coming in contact with substances with which it can react.

The fact mentioned by Bunsen and Roscoe that an active mixture of hydrogen and chlorine becomes inactive on standing is due to their experiments having been performed in glass vessels. On substituting quartz for glass it has been shown by the authors that no such decay occurs. The decay observed in the former case they believe to be due to the slow action on the chlorine of some impurity contained in the glass.

Ordinary Meeting, February 7th, 1905.

Professor H. B. DIXON, M.A., F.R.S., Vice-President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. R. S. HUTTON, M.Sc., and Mr. CHARLES OLDHAM

were nominated auditors of the Society's Accounts for the session 1904-1905.

Mr. THOMAS THORP, F.R.A.S., exhibited his new direct-vision spectroscope and explained its construction.

The dispersion of direct-vision spectroscopes of the ordinary kind is effected by means of a fixed compound prism, the surface nearest the eye being at an angle of 45° with the axis of the instrument. This surface is utilised to reflect a scale or pointer into the field of view, which can be made to travel along the spectrum, and so enable readings of the positions of the well-known bright and dark lines to be made. The accuracy of the readings is, however, not uniform, as the spectrum is not a normal one, being extended at the blue end and contracted at the red end.

In Mr. Thorp's instrument the dispersion is effected by means of a transparent grating of about 14,500 lines to the inch, mounted on the long face of a light crown prism having a refracting angle of about 37° to secure direct vision. This prism-grating is mounted in a hinged frame and adjusted so that the grating face is at an angle of 45° with the axis of the instrument when the frame is at the centre of its range of motion. A spring holds the frame tightly against the end of a micrometer screw having a graduated head, this head being in the focus of a lens placed near the ocular of the spectroscope so that it can be read off without taking the instrument away from the eye. The pointer, which is a small triangular aperture in a metal plate, illuminated by the source of light under observation, is placed, as usual, in the focus of a collimating lens and deflected on to the posterior surface of the grating by means of a total reflecting prism. On now turning the micrometer screw by means of a milled head, the pointer is seen to move along the spectrum by reason of the alteration in the position of the prism-grating which, however, does not affect the spectrum in any appreciable degree, and the positions of the bright and dark lines can be read off with the same degree of accuracy from end to end of the spectrum, it being almost

exactly a normal one. The D lines can just be separated in the pocket instrument, and readings can be made by taking the mean of several to about one Angstrom unit.

Mr. F. A. BRUTON, M.A., exhibited some leaden weights found at Melandra Castle, an old Roman edifice near Glossop, among them being the uncia, or ounce, and other weights related thereto.

At this point the chair was taken by Mr. FRANCIS NICHOLSON, F.Z.S.

Professor H. B. DIXON, M.A., F.R.S., stated that during the last two years he had made, in conjunction with Mr. E. C. EDGAR, a direct determination of the atomic weight of chlorine by burning a known weight of hydrogen in a known weight of chlorine. The hydrogen was occluded in palladium and so weighed; the chlorine was prepared by the electrolysis of silver chloride, and was weighed in the liquid state. The atomic weight comes out about 35·192, higher than the accepted number by ·012. This higher value is of interest in view of the recent (unpublished) work of Professor Theodore Richards, of Harvard, who obtains a value ·019 higher than the accepted atomic weight.

Mr. CHARLES OLDHAM read a paper entitled, "**On the occurrence in Britain of the Pacific Eider** (*Somateria v-nigrum*, Gray), **a species new to the European avifauna.**" The bird, which was exhibited by the kindness of Mr. Fred Stubbs, of Oldham, was shot out of a flock at Graemsay, Orkney, by a wild-fowler named George Sutherland, in December, 1904. Its known habitat is the Behring Sea. Mr. Stubbs has presented the specimen to the Oldham Public Museum.

Mr. OLDHAM also read a paper entitled, "**Some Habits of Bats, with special reference to the Lesser Horse-shoe Bat** (*Rhinolophus hipposiderus*)."

Lantern slides of bats inhabiting the caves around Alderley Edge were exhibited.

Ordinary Meeting, February 21st, 1905.

Professor H. B. DIXON, M.A., F.R.S., Vice-President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. R. S. HUTTON, M.Sc., exhibited and described several forms of electrically-heated carbon tube furnaces, which he has designed in collaboration with Mr. W. H. PATTERSON, B.Sc. These furnaces are intended for experimental work, and not only enable extremely high temperatures to be attained, but with them the temperature, being under perfect control, can be kept steady at any value up to the maximum. It is hoped that the simple construction of the furnace will render possible a more detailed study of the effects of high temperature on chemical and physical changes than has yet been carried out and thus open up a wide field of research.

Special Meeting, February 28th, 1905.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The PRESIDENT said the meeting was held to present the Wilde Medal awarded during this session, and to hear the Wilde Lecture.

In awarding the Wilde Medal for 1905 to Dr. LAPWORTH, F.R.S., LL.D., Professor of Geology and Geography in the University of Birmingham, the Council marks its sense of the value of his services in advancing knowledge by numerous contributions to the Ancient History of the Earth during the last 35 years. These contributions have already been recognised by the Geological Society of London in 1887 by the award of the Bigsby Medal, and in 1899 by the Wollaston Medal, and by

the Royal Society in 1891 by the Royal Medal. When he began his work in 1870, the classification of the older Welsh rocks was a battleground between two rival schools, and the Scotch Highlands, North and South, presented a problem which defied the efforts of the Scotch Geological Survey, and of the best amateur geologists of the day. In defining the Ordovician Period he ended the controversy between the followers of Sedgwick and those of Murchisson, and set at rest for ever the vexed question of the boundary of the Cambrian and Silurian systems. In dealing with the Southern Highlands, he first of all discovered and pointed out the invariable sequence of *various* forms of Graptolites in the Silurian strata, and established their definite zones. Then he used these zones to work out, with unwearied labour, the complex faults and foldings, thus laying the foundation for the subsequent maps and memoirs of the Geological Survey on this most difficult region. Since that time his classification by zones of Graptolites has been found to apply to the whole of the Silurian rocks of the British Isles, and to all the foreign regions in which it has been tested.

His work in the Northern Highlands is of the same high order. In 1882 he began work in the districts of Durness and Eriboll, by marking down certain zones of rock by physical character (—for there were no fossils to guide him—) and gradually established the true sequence of the strata, and the wonderful overthrust faulting and smashing of the rocks. Here again he proved a guide to the Geological Survey, whose memoirs and maps show that the Highlands have a structure analogous, but, if possible, more complicated than that of the Alps.

In 1886 he turned his attention to the Shelve district of Shropshire, and after two years work discovered the true base of the Cambrian rocks characterised by Olenellus and its accompanying fauna, at the top of the basal Shropshire Quartzite. This was followed later by the discovery of the Olenellus zone at Nuneaton, and led directly to the finding of Olenellus in the Fucoid Beds of the Highlands. Thus a definite Lower Cam-

brian horizon identical with that of North America and the Continent became marked over a large area in the British Isles.

These discoveries stand out above many others which Professor Lapworth has made in a long and energetic life, as landmarks in British Geology. For these, more especially, the Council has selected him to join the company of the leaders of thought to whom the Wilde Medal has been awarded in past times. We regret that he is unable to be here to receive it, and hope that he will soon be restored to his usual health and energy.

The SECRETARY then read the following letter from Professor Lapworth :—

"SIR,

"Please convey to the President and Council my sincere "apologies and regrets that owing to illness I am unable to "attend the Meeting of the Society on the 28th, and thank "them in person for the honour which they have done me "by the award of the Wilde Medal.

"I enclose with this a short expression of my thanks, "which I shall be glad if you will read at the proper time.

"I am, Sir,

"Very truly yours,

"CHARLES LAPWORTH."

Reply of Professor LAPWORTH on being awarded the Medal :—

"Mr. PRESIDENT,

"SIR,

"I am, indeed, grateful to the Council of the Manchester "Literary and Philosophical Society for the distinction "which they have conferred upon me by the award of the "Wilde Medal. I am well aware that there are other "British geologists more deserving of this honour, but I "may perhaps presume that the Council have selected me,

"not so much as an individual, but as a more or less "average representative of the British geologist in general.

"Our science of geology is many-sided, and its votaries "are of many kinds. It owes its advance not only to the "so-called professional geologist, but almost as much to the "so-called amateur. Its progress is due to the student "quite as much as to the teacher, and to the heterodox in "geological opinion quite as much as to the orthodox; to "the man carrying into practice its economic applications "as to the man absorbed in theoretical geology; and, I am "bound to confess, to the outsider (versed in other sciences) "almost as much as to the insider.

"The formal teacher of geological science may very pro- "perly pride himself upon the fact that in his lectures and "his laboratories are instilled into the student the accepted "principles and practice of the science; but it is to the "enthusiastic student himself—the man who remains a "learner all his life—that our science looks most hopefully "for its advance, and never looks in vain.

"To the staunchly orthodox professor of geology, conser- "vative of the authoritative and the accepted, and naturally "suspicious of novelty, we owe the dignity and stability of "our science and the wide influence it has gained in the "worlds of philosophy and practice. But our science owes "perhaps quite as much to men whose training, or want of "training, leads them to look at things from what for the "time is the heretical point of view: men whose tempera- "ment prompts them to question every geological opinion "that admits of a doubt, or of an alternative explanation. "Again and again have these venturesome pioneers opened "out new and almost undreamt of paths in the science, and "their very mistakes have proved admirable guide-posts for "their successors.

"And, certainly, foremost among those who have always "advanced our science and are daily extending its influence "are those who deal with its practical applications, in

"Mining, and Agriculture and Engineering. We can never "forget that to the art of Mining belongs the origin of our "science, and that Mining still includes perhaps the majority "of geological pupils. In the most modern works of Civil "Engineering, in the making of canals, of railroads, and in "those great municipal waterwork undertakings, lie some of "the grandest applications of geological science to the service "of humanity—applications that may be understood and "appreciated by all.

"Now, there is much to be said in support of the opinion "that no one can become proficient in, or even fairly con- "versant with, more than a single branch or aspect of "geology. But, on the other hand, there is also something "to be urged for the view that no one can fully sympathise "with, or appreciate the motives and the conquests of the "various workers in the science who has not studied it from "many points of view. Here, indeed, I can claim some "experience. Circumstances have so brought it about that "during my geological career I have been forced to be "in turn amateur and professional, student and teacher, "heterodox and orthodox, a theorist and also a worker at "the practical applications of the science. Nor would I "willingly be without this experience, for it enables one, at "least in part to understand that absorbing love of their "science, which, under all these diversities of aspect and of "method, distinguishes British geologists as a class. And, "in their name, rather than in my own, I thank you for the "honour which you have done us.

"CHAS. LAPWORTH."

Dr. D. H. Scott, F.R.S., of Kew, then delivered the Wilde Lecture, entitled: **"The Early History of Seed-bearing Plants, as recorded in the Carboniferous Flora."**

Ordinary Meeting, March 7th, 1905.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. C. E. STROMEYER, M.Inst.C.E., gave notice that on April 4th he would move the following resolution :—

"The Council of the Literary and Philosophical Society is hereby instructed annually to prepare two nomination lists, one list of Members of Council and one list of Office Bearers.

The nomination list of Members of Council is to be prepared in harmony with the idea that the leading interests of Manchester and surrounding districts shall, as far as practicable, be represented in due proportion, except as regards the Past President, to be referred to later. This list shall contain the names of the retiring Members of Council, and at least five more names than there are vacancies to be filled.

The President being customarily elected to his position for two successive years, shall be nominated from amongst the retiring President and Vice-Presidents.

The list of Vice-Presidents shall contain two more names than there are vacancies to be filled, and shall contain the names of the retiring Vice-Presidents, not being Past President, the name of the immediate Past President, and the names of other Members of the retiring Council.

The list of office bearers shall contain the names of the retiring Members of the Council.

The Nomination Lists of Members of Council and of office bearers shall be used as balloting papers, and members should be instructed how to use them.

The names of members who are not elected as Members of Council if appearing on the balloting lists of office bearers shall not count."

Mr. D. L. CHAPMAN, M.A., communicated a paper entitled **"Two New Aldehyde Reactions,"** by W. B. RAMSDEN, B.Sc., M.B., Ch.B.

General Meeting, March 21st, 1905.

Professor W. Boyd Dawkins, D.Sc., F.R.S., President, in the Chair.

Mr. W. H. Sutcliffe, F.G.S., of *Shore, Littleborough*, was elected an ordinary member of the Society.

Ordinary Meeting, March 21st, 1905.

Professor W. Boyd Dawkins, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. The following were among the recent accessions to the Society's Library:—"*Rapporten v. d. Commissie in Ned.-Indië voor Oudheidkundig Onderzoek...1901, 1902*" (4to., Batavia, 1904), presented by the Bataviaasch Genootschap van Kunsten en Wetenschappen; "*Die Halophänomene in Russland*," von E. Leyst (8vo., Moscow, 1903), presented by the Meteorol. Observ. d. Kaiserl. Univ. Moskau; "*Systematisk gennemforte termokemiske...Resultater.* By J. Thomsen (8vo., Copenhagen, 1905), presented by the Kongeligt Dansk Videnskabernes Selskab; "*Le Opere di Galileo Galilei*," vol. 15 (4to., Firenze, 1904), presented by the Italian Government; "*Inebriety, its source, prevention, and cure.*" By C. F. Palmer (12mo., New York, etc., 1905), presented by the Union Press, Philadelphia; "*Das Problem der neugriechischen Schriftsprache*," von K. Krumbacher (4to., München, 1903), "*Ueber Wert und angeblichen Unwert der Mathematik*, von A. Pringsheim (4to., München, 1904), "*Zum Andenken an Karl von Zittel*," von K. Th. von Heigel (4to., München, 1904), "*Konrad von Maurer*," von K. von Amira (4to., München, 1903), presented by the K. B. Akademie der Wissenschaften zu München.

Mr. CHARLES OLDHAM exhibited an example of a new species of Vole from the Orkney Islands (*Microtus orcadensis*, Millais), described by Mr J. G. Millais in the July number of the *Zoologist* for 1904.

Dr. W. E. HOYLE, F.R.S.E., exhibited a series of maps illustrating the gradual extermination of the bison in North America.

Mr. HENRY SIDEBOTTOM read a paper entitled, **"On Nevillina, a New Genus of Foraminifera."**

Drawings were exhibited of the only species as yet found in this genus.

Messrs. H. MORRIS-AIREY, M.Sc., and E. D. SPENCER read a paper entitled **"On the Temperature Coefficient of Electrical Resistivity of Carbon at Low Temperatures."**

General Meeting, April 4th, 1905.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The resolution, of which Mr. C. E. STROMEYER, M.Inst.C.E., had previously given notice, was referred to the Council for their consideration in order that they might afterwards report upon it to the Society.

Ordinary Meeting, April 4th, 1905.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Professor F. E. WEISS, D.Sc., F.L.S., exhibited on behalf of Mr. J. Lomax, of Bolton, a portion of a stem of *Sigillaria vascularis* giving off a branch with the structure of *Lepidodendron*

selaginoides thus confirming Dr. Williamson's conviction of the identity of these two Coalmeasure plants.

Mr. F. A. BRUTON, M.A., exhibited a photograph of the foundation of the western part of the Northern Gateway at Melandra Castle, now uncovered for the first time.

Dr. H. RAMSDEN exhibited a model which he had devised to illustrate the propagation of sound waves. It consists of a series of magnetised needles, suspended vertically so as to vibrate in the same plane with their like poles downwards, and is designed to show (since the needles were constructed and regulated to have equal times of oscillation) most of the phenomena of the longitudinal transmission of waves.

Miss C. COIGNOU exhibited and described some lantern slides illustrating the new laboratory of the Manchester High School for Girls.

Mr. FRANCIS NICHOLSON, F.Z.S., read a paper entitled, **"Notes on the Wilkinsons, Ironmasters."**

ANNUAL GENERAL MEETING, APRIL 18TH, 1905.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The Annual Report of the Council and the Statement of Accounts were presented, and it was resolved:—"That the Annual Report, together with the Statement of Accounts, be adopted, and that they be printed in the Society's *Proceedings*."

Mr. W. H. TODD and Mr. H. B. KNOWLES, M.A., were appointed Scrutineers of the balloting papers.

The following members were elected officers of the Society and members of the Council for the ensuing year:—

President: SIR WILLIAM H. BAILEY.

Vice-Presidents: H. B. DIXON, M.A., F.R.S.; HORACE LAMB, LL.D., D.Sc., F.R.S.; W. BOYD DAWKINS, D.Sc., F.R.S.; FRANCIS NICHOLSON, F.Z.S.

Secretaries: FRANCIS JONES, M.Sc., F.R.S.E., F.C.S.; CHARLES H. LEES, D.Sc.
Treasurer: ARTHUR McDOUGALL, B.Sc.
Librarian: W. E. HOYLE, M.A., D.Sc., F.R.S.E.
Other Members of the Council: C. E. STROMEYER, M.Inst.C.E.; W. THOMSON, F.R.S.E., F.C.S.; THOMAS THORP, F.R.A.S.; CHARLES BAILEY, M.Sc., F.L.S.; R. L. TAYLOR, F.C.S., F.I.C.; CHARLES OLDHAM.

Ordinary Meeting, April 18th, 1905.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. F. J. FARADAY, F.L.S., presented to the Society's Library a copy of "The Life of Thomas Fuller, D.D., with notices of his books, his kinsmen, and his friends." By J. E. Bailey. 1874.

Mr. H. STANSFIELD, B.Sc., exhibited a new method of producing coloured diffusion bands. One surface of a piece of plate glass, rendered diffusive by spoiling the polish or coating it with a diffusing film of resin or butter, was fixed so as to be nearly in contact with the reflecting surface of a polished silver mirror, the surfaces being separated at the corners by a single thickness of stamp-edging. Greater dispersion of the colours is obtained in this way than by breathing on the glass surface of a silvered mirror, as the air film can be made much thinner than the mirror glass. A diffusion mirror whose glass surface had roughly parallel grease markings, imitated the action of a diffraction grating. One of Mr. Thorp's transparent diffraction gratings, backed up with a silver surface in the same way, showed a variety of diffusion effects superposed on the diffraction spectra,

and also showed the bands that may be obtained by superposing two transparent gratings, or by looking at one row of railings through another row.

Mr. C. H. BURGESS, M.Sc., read a paper, written by himself in collaboration with Mr. D. L. CHAPMAN, M.A., entitled **"Note on Chlorine."**

General Meeting, May 2nd, 1905.

Sir WILLIAM H. BAILEY, President, in the Chair.

Dr. W. A. BONE, F.R.S., Lecturer on Chemistry and Metallurgy in the University of Manchester, *Rokeby House, Errwood Road, Levenshulme;* Miss MARIE C. STOPES, B.Sc., Ph.D., Demonstrator of Botany in the University of Manchester, *11, Kensington Avenue, Victoria Park, Manchester;* Mr. ERNEST FEARON, Chemist to the Salford Corporation Gas Works, *Hundon House, Arnold Road, Alexandra Park, Manchester*, were elected ordinary members of the Society.

Ordinary Meeting, May 2nd, 1905.

Sir WILLIAM H. BAILEY, President, in the Chair.

The PRESIDENT, who occupied the chair for the first time, in a short address thanked the members for his election, and said he would do all in his power to carry on the traditions of the Society.

The thanks of the members were voted to the donors of the books upon the table. The following were among the recent accessions to the Society's Library:—"*Bibliographia Geologica*" ...par M. Mourlon, Ser B. Tome vii. (8vo., Bruxelles, 1904), purchased; "*Reports to the Evolution Committee of the Royal Society*," ii. (8vo., London, 1905), presented by the Royal Society; "*History of the Collections contained in the Natural*

History Departments of the British Museum," vol. i. (8vo., London, 1904), "*A Guide to the Fossil Mammals and Birds in the Department of Geology and Palæontology of the British Museum (N.H.)*," 8th ed. (8vo., London, 1904), "*Guide to the Gallery of Birds in the Department of Zoology of the British Museum (N.H.)*," (8vo., London, 1905), "*Catalogue of the Mesozoic Plants in the Department of Geology of the British Museum (N.H.). The Jurassic Flora.*" Pt. 2 (8vo., London, 1904), presented by the British Museum.

Professor H. H. FIELD, of Zurich, described a method of card-bibliography by which reference to all the work done in any branch of biology became a simple matter. The Manchester Museum, at the University, is in possession of a complete set, a portion of which was exhibited.

Professor E. KNECHT, Ph.D., read a paper entitled "**On some Constituents of Manchester Soot.**" An interesting discussion followed the reading of the paper, in which the President, Professor F. E. Weiss, Professor R. B. Wild, Dr. Bowman, and others took part.

Annual Report of the Council, April, 1905.

The Society began the session with an ordinary membership of 159. During the present session 8 new members have joined the Society; 10 resignations have been received, and there has been one death, *viz.*: Dr. GEORGE WILSON. This leaves on the roll 156 ordinary members. The Society has also lost, by death, 2 honorary members, *viz.*: Mr. BEAUCHAMP TOWER, M.Inst.C.E., and Dr. ALEXANDER W. WILLIAMSON, F.R.S., and two corresponding members, *viz.*: the Rev. Dr. BROOKE HERFORD and Dr. AUGUSTE FRANÇOIS LE JOLIS, of Cherbourg. Memorial notices of these gentlemen appear at the end of this report.

The Society commenced the session with a balance in hand of £369. 10s. 5d., from all sources, this amount being made up of the following balances:—

At the credit of General Fund	£97	13	1
„ „ Wilde Endowment Fund...	181	4	8
„ „ Joule Memorial Fund	57	2	0
„ „ Dalton Tomb Fund.....	33	10	8
	£369	10	5

The total balance in hand at the close of the session amounted to £351. 5s. 6d., and the amounts standing at the credit of the separate accounts, on the 31st March, 1905, are the following:—

At the credit of General Fund	£18	5	4
„ „ Wilde Endowment Fund...	233	16	6
„ „ Joule Memorial Fund.....	64	16	6
„ „ Dalton Tomb Fund.....	34	7	2
Cash in hand 31st March, 1905	£351	5	6

The Wilde Endowment Fund, which is kept as a separate banking account, shows a balance of £233. 16s. 6d. in its favour, as against £181. 4s. 8d., at the beginning of the financial year, the receipts from the invested funds being the same as last year.

No expenditure has been incurred in respect of the Joule Memorial Fund and the Dalton Tomb Fund, the balances of which remain at the amounts stated above. The Dalton Tomb Fund stands as a separate account at the Manchester and Salford Savings Bank.

The Librarian reports that during the session 826 volumes have been stamped, catalogued and pressmarked, 756 of these being serials, and 70 separate works. There have been written 602 catalogue cards, 485 for serials, and 117 for separate works. The total number of volumes catalogued to date is 28,365 for which 9,729 cards have been written.

Satisfactory use is made of the library for reference purposes, but the number of volumes consulted is not recorded. During the session, 134 volumes have been borrowed from the library, as compared with 184 in the previous session.

Some attention has continued to be paid to the completion of sets, 13 volumes having been obtained which render two sets complete, whilst 111 volumes or parts have been acquired which partly complete seven sets. Of these, 52 volumes or parts were purchased, and the rest were presented by the respective societies publishing them.

A larger amount of binding has been done this session, 257 volumes having been bound in 204.

A record of the accessions to the library shows that, from April, 1904, to March, 1905, 731 serials and 50 separate works were received, a total of 781 volumes. The donations during the session (exclusive of the usual exchanges) amount to 47 volumes and 41 dissertations; 3 volumes have been purchased (in addition to the periodicals on the regular subscription list).

During the past session the Society has arranged to exchange publications with the following:—The South African Association

for the Advancement of Science; The College of Science and Engineering, Kyoto Imperial University; Cuerpo de Ingenieros de Minas del Peru; The Springfield Museum of Natural History; The North Staffordshire Naturalists' Field Club and Archæological Society, and The State Geological and Natural History Survey of Connecticut.

The publication of the *Memoirs and Proceedings* has been continued under the supervision of the Editorial Committee.

During the session, 1903-1904, there was a marked increase in the number of papers read and afterwards printed in the *Memoirs and Proceedings*, there being no fewer than twenty-five, making a volume, together with the Proceedings, of 441 pages. This was illustrated by 29 plates, 2 tables, and 37 text figures.

The volume for the previous session, 1902-03, comprised only fifteen papers, and numbered, with the Proceedings, 296 pages. It contained only 7 plates and 40 text figures.

The Society is indebted to the following gentlemen for the undermentioned gifts :—

Mr. C. L. Barnes, for a copy of Dr. F. W. Jordan's "Biography of Dr. Joseph Jordan."

Mr. C. Davies Sherborn, for a small 4to MS. volume, being a catalogue of books and prints purchased by Lt.-Col. J. Leigh Philips, of Manchester.

Mr. Francis Nicholson, for a copy of Dr. C. J. Cullingworth's "Life of Charles White, F.R.S.," and for a framed portrait of Dr. John Ferriar, engraved by Bartolozzi, after Stothard.

The Council of the Victoria University of Manchester, for 5 volumes of "The Oxford, Cambridge, and Dublin Messenger of Mathematics."

Mr. A. W. Waters, for a copy of his work, entitled "Resultats du voyage du S. Y. Belgica en 1897—1898—1899...Rapports scientifiques...Zoologie. Bryozoa," 1904.

A member of the Society, for an oil painting of Sir Isaac Newton investigating his first spectrum, by Mr. Lavender, of Southport.

The Rev. BROOKE HERFORD, D.D., was the youngest son of John and Sarah Herford, and was born at Altrincham on 21st February, 1830. His father was of a Devonshire family, but was a native of Upton-on-Severn. His mother came from Birmingham, and carried on a school at Altrincham, while her husband established himself as a wine merchant at Manchester. On the mother's death the family moved into Manchester, when Brooke Herford was about two years old. He spent some years at the Rev. J. R. Beard's school before being apprenticed to his father's business; but before long he came under the influence of Travers Madge at the Lower Mosley Street Schools, where Brooke Herford and his elder brother Charles had become teachers, and he determined to be a minister. This was decidedly in opposition to his father's wishes. He entered Manchester New College (then at Manchester) in October, 1848, and continued as a student there until the spring of 1851, when, as a young man of twenty-one, he settled as minister of the Unitarian congregation at Todmorden. Five years later he was appointed minister of the Upper Chapel at Sheffield. There he remained nearly nine years, becoming a man of considerable influence, not only in his own denomination, but as a strenuous worker for general social reform. In 1860 he began the issue of "Home Pages," a series of popular Unitarian tracts, which he continued until 1867. Towards the close of 1861 he delivered a courageous address at Sheffield on "Trade Outrages," occasioned by some shocking attacks committed by trade unionists on non-union men. In October, 1864, he succeeded Dr. Beard as minister of the Strangeways Chapel, Manchester. His memoir of Travers Madge was published in 1867. He was then joint editor of the *Unitarian Herald.* On the death of his friend, John Harland, in 1868, he undertook to complete the new and revised edition of Baines's "History of Lancashire," of which only the first volume had been published by Harland. Herford had a keen interest in history and antiquarian subjects, and finished his laborious task of editing the second and concluding volume in a very creditable manner. It was about this time that he joined

the Literary and Philosophical Society, and the Chetham Society. At a later date he published an admirable "Story of Religion in England," and a series of articles in the *Atlantic Monthly*, in which he argued for more historical reality than recent critics have been inclined to allow. After eleven years of active ministerial service at Strangeways, he accepted an invitation to America, and early in 1876 became minister of the Church of the Messiah in Chicago. In six years he removed to Boston, as minister of the Arlington Street Church, where he remained until the autumn of 1891. It was during his residence at Boston that he was elected on November 14th, 1882, a corresponding member of this Society. In America he gained a position of great influence and honour among the Unitarian ministers of that continent. He received his degree of D.D. from Harvard University in 1891, after preaching a course of sermons at that seat of learning. On returning to England he succeeded Dr. Sadler at Rosslyn Hill Chapel, Hampstead, retiring through ill-health in 1901, having completed fifty years of ministerial service. The occasion was taken by a number of friends in England and America to make a personal gift to him of over £3,200, with warm expressions of gratitude and affection. His life was one of great happiness and abundant activity, spent in fearless advocacy of social justice and freedom of religious thought. Besides the writings mentioned above he published several volumes of addresses, which reflect his healthy, cheery, and inspiring mind. He died at Hampstead on December 20th, 1903, and was interred at Hale Chapel, Cheshire. His wife died in 1891. She was Hannah, daughter of Mr. William Hankinson, of Hale, and was married to Brooke Herford in 1852. C. W. S.

Dr. Auguste François Le Jolis (born at Cherbourg 1st December, 1823, died at Cherbourg, 20th August, 1904) was a corresponding member of our Society for the long span of 45 years, having been elected to that position on the 25th January, 1859. As a British vice-consul, judge, president of a chamber of

commerce, and merchant, he gave valuable services to the community in which he lived, but his hours of relaxation were devoted to the life-study of the cryptogams of his native land, more particularly the seaweeds, hepatics and mosses of the Département in which he spent all his life. He was one of the founders, more than fifty years ago, of the "Société des sciences naturelles et mathématiques de Cherbourg."

His friend, Monsieur Ed. Bornet, has published an appreciative obituary notice in the "*Bulletin de la Société Botanique de France*," vol. 51, pp. 428—429. C. B.

By the death of Mr. BEAUCHAMP TOWER, which occurred on December 31st, 1904, the Society has lost one of its honorary members, and one well known as an eminent engineer. Mr. Tower was born on January, 13th, 1845, and on completing his school education became a pupil of Messrs. Sir W. G. Armstrong & Co., from April, 1861, to April, 1866. He had entire charge of the design and construction of several iron steam boats, at the Tyne Iron Works, and was assistant to the late Mr. W. Froude, F.R.S., M.Inst.C.E., in the design and construction of his experimental works for the Admiralty, from May, 1869, to June, 1872. Subsequently he was employed by Messrs. Armstrong & Co., in conducting a series of experiments on Torpedoes, and was engaged by Lord Raleigh, F.R.S., in conducting a series of experiments on the Theory of Sound during 1875 and 1876.

Mr. Tower is, perhaps, best known to engineers in general by his experiments on journal friction, carried out for the Institution of Mechanical Engineers. The first of his reports was published in November, 1883, and marked an epoch in our knowledge of the subject. Up till that date it had been considered that General Morin's experiments had established certain laws of friction which were of universal applicability. Practical engineers had, however, found it difficult to bring into accordance with these so-called laws their experience with actual journals; and it was this fact which led the Institution of

Mechanical Engineers to undertake the investigation, which they entrusted to Mr. Tower. These experiments showed conclusively that though Morin's laws might represent fairly the condition of a journal on the point of "seizing," they applied in no degree to the friction of a well-lubricated bearing. Thus, in place of the friction being proportional to the pressure, it was found to be, within wide limits, almost independent of it. Mr. Tower discovered that in the case of a well-lubricated journal the metal surfaces never touch, being separated by a continuous film of oil. The fact thus established has led to a revolution in the practice of lubrication. For example, high-speed journals are now provided with a supply of oil out of all proportion to what would have been considered sufficient in the early seventies; and as a consequence the tool-marks are now often still visible on a journal which has made some millions of revolutions.

The adoption of forced lubrication, and the great extension which the system of ring lubrication has taken within recent years, may justly be considered as the outcome of Mr. Tower's researches. Mr. Tower had some difficulty in interpreting his results, as he held that, the friction in a well-lubricated journal being found to be wholly fluid friction, the coefficient should vary as the square of the linear velocity of the rubbing surfaces; but, as a matter of fact, it was found to increase much less rapidly. The explanation was provided by Professor Osborne Reynolds, whose experiments showed that up to a certain critical velocity, fluid friction varied directly as the velocity, and not as the square. In fact, once the friction begins to vary as the square of the velocity, the lubricant ceases to lubricate.

Perhaps the great disappointment of Mr. Tower's life was the failure of the Admiralty to adopt his "steady platform" for guns and search-lights at sea. By a most ingenious gyroscopic device Mr. Tower succeeded in maintaining within half a degree the horizontality of a gun-platform mounted on shipboard, in spite of the oscillations of the vessel. The device was tested by the Admiralty, who certainly encouraged the inventor to devote

his time to these experiments; but who, finally, in spite of the success of the trials, decided that the apparatus was unsuitable for the service. The principal reason given for this decision was that the weight needed for the "steady platform" could be more usefully employed in carrying an extra gun or extra ammunition. Though naturally disheartened by this unexpected rebuff, Mr. Tower proceeded to adapt his steady platform for use on cross-channel steamers, the idea being to provide "steady seats," and thus rob the Channel passage of its present terrors for the bad sailor. He was engaged in this work at the time of his death. W. H. B.

By the death of Dr. ALEXANDER W. WILLIAMSON, F.R.S., which occurred last year, the Society has to lament the loss of one of its most distinguished honorary members. Although the number of separate contributions which Williamson made to science was not by any means large, yet he exercised a remarkable influence on the development of Chemical Theory. The son of a clerk in the East India House, Williamson was born on May 1st, 1824. As a child, and throughout his boyhood his health was always delicate, although he ultimately grew up to vigorous manhood. One of his eyes, however, was permanently useless, and with the other his vision was very imperfect; also, his left arm was partially paralysed. As a practical chemist these physical disadvantages must have greatly interfered with his work, although, as Professor Thorpe remarks in his admirably appreciative obituary notice of Williamson (*Nature*, May 12th, 1904), this very limitation of his physical powers probably conduced to his eminence as a speculative thinker. Williamson was, for many years, Professor of Chemistry in University College, London, where he succeeded Graham. His reputation mainly rests upon what has been well called his "epoch-making" paper on the "Theory of Ætherification," which was published in 1850. In this paper he not only proved, by a series of admirable experiments, what are the real changes which occur during the ordinary process of

etherification, but he also showed the existence of a series of mixed ethers. These researches practically introduced into chemistry the "water-type," a theory which, although now merged in the more comprehensive modern theories of chemical constitution, was, in the hands of Williamson, wonderfully fascinating and fertile.

The doctrine of types was always the basis of Williamson's teaching. As a lecturer, especially on organic chemistry, he was unexcelled. The writer of this notice will never forget the delight with which he used to listen to Williamson's lectures on organic chemistry. At that time (in the early seventies) it was quite a common thing for the Demonstrators and Assistants in the laboratory, and even the Assistant Professors, to join the students in the Lecture Theatre, to hear once more the master's exposition.

Williamson occupied many important and honourable positions in connection with the Royal, the Chemical, and other Societies. He was President of the British Association at the Bradford meeting in 1873, and General Treasurer of that Association from 1874 to 1891. He was elected an honorary member of our Society in 1889. He retired from active work in 1887, living afterwards in such seclusion that he was practically unknown to the younger generation of chemical workers.

He died at his house at Hindhead, on May 6th, 1904.

R. L. T.

The Obituary Notice of Dr. GEORGE WILSON could not be prepared in time to be inserted here, and will therefore appear in the next volume.

NOTE.—The Treasurer's Accounts of the Session 1904-1905, of which the following pages are summaries, have been endorsed as follows:

April 11th, 1905. Audited and found correct.

We have also seen, at this date, the certificates of the following Stocks held in the name of the Society:—£1,225 Great Western Railway Company 5% Consolidated Preference Stock, Nos. 12,293, 12,294, and 12,323; £258 Twenty years' loan to the Manchester Corporation, redeemable 25th March, 1914 (No. 1564); £7,500 Gas Light and Coke Company Ordinary Stock (No. 6,389); and the deeds of the Natural History Fund, of the Wilde Endowment Fund, those conveying the land on which the Society's premises stand, and the Declaration of Trust.

Leases and Conveyance dated as follow:—

22nd Sept., 1797.
23rd Sept., 1797.
25th Dec., 1799.
" " "
22nd Dec., 1820.
23rd Dec., 1820.

Declarations of Trust:—

8th Jan., 1878.
24th June, 1801.
23rd Dec., 1820.
30th April, 1851.

We have also verified the balances of the various accounts with the bankers' pass books.

(Signed) R. S. HUTTON.
CHAS. OLDHAM.

MANCHESTER LITERARY AND

Dr. *Arthur McDougall, Treasurer, in Account with th*

		£ s. d.	£ s. d
To Cash in hand, 1st April, 1904			154 15 1
To Members' Subscriptions :—			
Half Subscriptions, 1903-04,	4 at £1 1s. 0d.	4 4 0	
,, ,, 1904-05,	10 ,, ,,	10 10 0	
Subscriptions :— 1901-02,	1 ,, £2. 2s. 0d.	2 2 0	
,, 1902-03,	2 ,, ,,	4 4 0	
,, 1903-04,	10 ,, ,,	21 0 0	
,, 1904-05,	111 ,, ,,	233 2 0	
,, 1905-06,	1 ,, ,,	2 2 0	
			277 4 0
To Transfers from the Wilde Endowment Fund			79 8 0
To Sale of Publications			29 10 4
To Dividends :—			
Natural History Fund		58 5 0	
Joule Memorial Fund		7 7 2	
			65 12 2
To Income Tax Refunded :—			
Natural History Fund		2 17 5	
Joule Memorial Fund		0 7 4	
			3 4 9
To Donation from Dr. W. G. Black			2 2 0
To Discount on Knowles' bill			0 0 10
			£611 17 2

NATURAL HISTORY

	£ s. d.
To Dividends on £1,225 Great Western Railway Company's Stock	58 5 0
To Remission of Income Tax, 1904	2 17 5
	£61 2 5

JOULE MEMORIAL

	£ s. d.
To Balance, 1st April, 1904	57 2 0
To Dividends on £258 Loan to Manchester Corporation	7 7 2
To Remission of Income Tax, 1904	0 7 4
	£64 16 6

WILDE ENDOWMENT

	£ s. d.
To Balance 1st April, 1904	181 4 8
To Dividends on £7,500 Gas Light and Coke Company's Ordinary Stock	313 16 9
To Remission of Income Tax, 1904	15 9 4
To Bank Interest	2 13 11
	£513 4 8

DALTON TOMB

	£ s. d.
To Balance, 1st April, 1904	33 10 8
To Bank Interest	0 16 6
	£34 7 2

PHILOSOPHICAL SOCIETY.

Society, from 1st April, 1904, to 31st March, 1905. **Cr.**

	£ s. d.	£. s. d.
By Charges on Property :—		
Chief Rent (Income Tax deducted)	12 5 8	
Income Tax on Chief Rent	0 12 11	
Insurance against Fire	13 17 6	
		26 16 1
By House Expenditure :—		
Coals, Gas, Electric Light, Water, Wood, &c.	35 13 1	
Tea, Coffee, &c., at Meetings	14 18 5½	
Cleaning, Sweeping Chimneys, &c.	3 11 2	
		54 2 8½
By Administrative Charges :—		
Housekeeper	63 12 0	
Postages, and Carriage of Parcels and of "Memoirs"	40 16 10	
Stationery, Cheques, Receipts, and Engrossing	7 11 7	
Printing Circulars, Reports, &c.	16 19 8	
Extra attendance at Meetings, and during housekeeper's holidays	2 11 6	
Miscellaneous Expenses	3 1 0½	
		134 12 7½
By Publishing :—		
Printing "Memoirs and Proceedings"	177 3 9	
Illustrations for "Memoirs" (except Nat. Hist. papers)	32 4 9	
Binding "Memoirs"	4 0 0	
		213 8 6
By Library :—		
Books and Periodicals (except those charged to Natural History Fund) ..	39 0 8	
Periodicals formerly subscribed for by the Microscopical and Natural History Section	6 8 9	
		45 9 5
By Natural History Fund :—		
(Items shown in the Balance Sheet of this Fund below)	.. ..	54 6 0
By Joule Memorial Fund :—		
(No Expenditure this Session)		0 0 0
By Balance at Williams Deacon's Bank, 1st April, 1905	73 1 10	
,, ,, in Treasurer's hands	10 0 0	
		83 1 10
		£611 17 2

FUND, 1904—1905. (Included in the General Account, above.)

	£ s. d.
By Natural History Books and Periodicals	37 6 1
By illustrations for papers on Nat. Hist. in "Memoirs"	16 19 11
,, Balance, 1st April, 1905	6 16 5
	£61 2 5

FUND, 1904—1905. (Included in the General Account, above.)

	£ s. d.
(No expenditure this Session).	
By Balance, 1st April, 1905	64 16 6
	£64 16 6

FUND, 1904—1905.

	£ s. d.
By Assistant Secretary's Salary, April, 1904, to March, 1905	120 0 0
By Maintenance of Society's Library :—	
Binding and Repairing Books £33 13 2	
Periodicals to complete sets 6 0 0	
	39 13 2
By Repairs to Society's Premises	4 10 6
By Gold Medal and Engraving same	19 19 0
By Honorarium to Lecturer. 1905	15 15 0
By Transfers to Society's Funds	79 8 0
By Cheque Book	0 2 6
By Balance at District Bank, 1st April, 1905	233 16 6
	£513 4 8

FUND, 1904-1905.

	£ s. d.
(No Expenditure this Session).	
By Balance at Manchester and Salford Savings Bank, 1st April, 1905	34 7 2
	£34 7 2

THE COUNCIL
AND MEMBERS
OF THE
MANCHESTER
LITERARY AND PHILOSOPHICAL SOCIETY.

CORRECTED TO JULY 25TH, 1905.

President.

SIR WILLIAM H. BAILEY, M.I.Mech.E.

Vice-Presidents.

H. B. DIXON, M.A., F.R.S., F.C.S.
HORACE LAMB, M.A., LL.D., D.Sc., F.R.S.
W. BOYD DAWKINS, M.A., D.Sc., F.R.S.
FRANCIS NICHOLSON, F.Z.S.

Secretaries.

FRANCIS JONES, M.Sc., F.R.S.E., F.C.S.
CHARLES H. LEES, D.Sc.

Treasurer.

ARTHUR McDOUGALL, B.Sc.

Librarian.

W. E. HOYLE, M.A., D.Sc., F.R.S.E.

Other Members of the Council.

C. E. STROMEYER, M.Inst.C.E.
WILLIAM THOMSON, F.R.S.E., F.C.S.
THOMAS THORP, F.R.A.S.
CHARLES BAILEY, M.Sc., F.L.S.
R. L. TAYLOR, F.C.S., F.I.C.
CHARLES OLDHAM.

Assistant Secretary and Librarian.

A. P. HUNT, B.A.

ORDINARY MEMBERS.

Date of Election.

1901, Dec. 10. Adamson, Harold. *Oaklands Cottage, Godley, near Manchester.*

1902, Mar. 18. Allen, J. Fenwick. 147, *Withington Road, Whalley Range, Manchester.*

1902, Jan. 21. Allott, Charles S., M.Inst.C.E. 519, *Stretford Road, Old Trafford, Manchester.*

1870, Dec. 13. Angell, John, F.C.S., F.I.C. 6, *Beaconsfield, Derby Road, Withington, Manchester.*

1896, Jan. 31. Armstrong, Frank. 88, *Deansgate, Manchester.*

1895, Jan. 8. Armstrong, George B. *Clarendon, Sale, Cheshire.*

1865, Nov. 14. Bailey, Charles, M.Sc., F.L.S. *Atherstone House, North Drive, St. Annes-on-the-Sea, Lancs.*

1888, Feb. 7. Bailey, Alderman Sir William H., M.I.Mech.E. *Sale Hall, Sale, Cheshire.*

1895, Jan. 8. Barnes, Charles L., M.A. 8, *Swinton Avenue, Chorlton-on-Medlock, Manchester.*

1903, Oct. 20. Barnes, Jonathan, F.G.S. *South Cliff House*, 301, *Great Clowes Street, Higher Broughton, Manchester.*

1896, April 14. Behrens, George B. *The Acorns*, 4, *Oak Drive, Fallowfield, Manchester.*

1895, Mar. 5. Behrens, Gustav. *Holly Royde, Withington, Manchester.*

1898, Nov. 29. Behrens, Walter L. 22, *Oxford Street, Manchester.*

1868, Dec. 15. Bickham, Spencer H., F.L.S. *Underdown, Ledbury.*

1901, Nov. 12. Bles, Abraham J. S. *Palm House, Higher Broughton, Manchester.*

1876, April 28. Bolton, Herbert, F.R.S.E. *The Museum, Bristol.*

1905, May 2. Bone, William A., D.Sc., F.R.S., Lecturer on Chemistry and Metallurgy in the University of Manchester. *Rokeby House, Errwood Road, Levenshulme, Manchester.*

1896, Oct. 6. Bowman, F.H., D.Sc., F.R.S.E. *Spinningfield, Deansgate, Manchester.*

1896, Feb. 18. Bowman, George, M.D. 594, *Stretford Road, Old Trafford, Manchester.*

1875, Nov. 16. Boyd, John. *Barton House*, 11, *Didsbury Park, Didsbury, Manchester.*

1902, Oct. 21. Bradley, Henry Wentworth. *Woodside, Wilmslow, Cheshire.*

1889, Oct. 15. Bradley, Nathaniel, F.C.S. *Sunnyside, Whalley Range, Manchester.*

Date of Election.

1861, April 2. Brogden, Henry, F.G.S., M.I.Mech.E. *Hale Lodge, Altrincham, Cheshire.*

1889, April 16. Brooks, Samuel Herbert. *Slade House, Levenshulme, Manchester.*

1860, Jan. 24. Brothers, Alfred. *Handforth, near Manchester.*

1886, April 6. Brown, Alfred, M.A., M.D. *Sandycroft, Higher Broughton, Manchester.*

1889, Jan. 8. Brownell, Thomas William, F.R.A.S. 64, *Upper Brook Street, Manchester.*

1902, Oct. 21. Bruton, F.A., M.A. 56, *Central Road, West Didsbury, Manchester.*

1889, Oct. 15. Budenberg, C. F., M.Sc., M.I.Mech.E. *Bowdon Lane, Marple, Cheshire.*

1894, Nov. 13. Burton, William, F.C.S. *The Hollies, Clifton Junction, near Manchester.*

1904, Oct. 18. Campion, George Goring, L.D.S. 264, *Oxford Street, Manchester.*

1903, Nov. 3. Capper, Stewart Henbest, M.A., Professor of Architecture in the Victoria University of Manchester. 337, *Moss Lane East, Manchester.*

1899, Feb. 7. Chapman, D. L., M.A., Assistant Lecturer and Demonstrator of Chemistry in the Victoria University of Manchester. *The University, Manchester.*

1901, Nov. 26. Chevalier, Reginald C., M.A., Mathematical Master at the Manchester Grammar School. 43, *Lansdowne Road, West Didsbury, Manchester.*

1902, Nov. 4. Clerk, Dugald, M.Inst.C.E., F.C.S. 18, *Southampton Buildings, Chancery Lane, London, W.C.*

1901, Nov. 12. Coignou, Caroline, Science Mistress at the Manchester High School for Girls. 60, *Cecil Street, Greenheys, Manchester.*

1895, April 30. Collett, Edward Pyemont. 8, *St. John Street, Manchester.*

1884, Nov. 4. Corbett, Joseph. *Town Hall, Salford.*

1903, Oct. 20. Core, William Hamilton, M.Sc. *Groombridge House, Withington, Manchester.*

1895, Nov. 12. Crossley, W. J., M.I.Mech.E. *Openshaw, Manchester.*

1904, Oct. 18. Crosthwaite, Robert, M.A. Camb., B.Sc. Lond., Head Master of the Municipal Secondary School, Whitworth Street. 26, *Palatine Road, Manchester.*

Date of Election.

1904, Jan. 5. Darbishire, Arthur D., M.A., B.Sc., Assistant Lecturer and Demonstrator of Zoology in the Victoria University of Manchester. *The University, Manchester.*

1901, Nov. 26. Darbishire, Francis V., B.A., Ph.D., Demonstrator and Analyst at the South Eastern Agricultural College. *The College, Wye, Kent.*

1895, April 9. Dawkins, W. Boyd, M.A., D.Sc., F.R.S., Professor of Geology in the Victoria University of Manchester. *Fallowfield House, Fallowfield, Manchester.*

1894. Mar. 6. Delépine, A. Sheridan, M.B., B.Sc., Professor of Pathology in the Victoria University of Manchester. *The University, Manchester.*

1887, Feb. 8. Dixon, Harold Baily, M.A., F.R.S., F.C.S., Professor of Chemistry in the Victoria University of Manchester. *The University, Manchester.*

1905, Jan. 10. Duffield, W. Geoffrey, B.A., B.Sc., Research Fellow in the University of Manchester. *The University, Manchester.*

1902, May 13. Ellison, Robert William. *'Brookside,' Crofts Bank Road, Urmston, Manchester.*

1883, Oct. 2. Faraday, F. J., F.L.S., F.S.S. *Carshalton House, Heaton Road, Withington, Manchester.*

1905, May 2. Fearon, Ernest, Chemist to the Salford Corporation Gas Works. *Hundon House, Arnold Road, Alexandra Park, Manchester.*

1903, Dec. 15. Fishenden, Richard B., Lecturer in Photo-Mechanical Processes at the Municipal School of Technology, Manchester. 311, *Moss Lane East, Manchester.*

1898, Nov. 29. Gamble, F. W., D.Sc., Assistant Lecturer and Demonstrator of Zoology in the Victoria University of Manchester. *The University, Manchester.*

1896, Nov. 17. Gordon, Rev. Alexander, M.A. *Memorial Hall, Albert Square, Manchester.*

1903, Oct. 20. Guppy, Henry, M.A., Librarian of the John Rylands Library. 57, *Parsonage Road, Withington, Manchester.*

1902, April 29. Herbert, Arthur M., B.A. *Frankwyn, Hale, Cheshire.*

Mechanical Engineers to undertake the investigation, which they entrusted to Mr. Tower. These experiments showed conclusively that though Morin's laws might represent fairly the condition of a journal on the point of "seizing," they applied in no degree to the friction of a well-lubricated bearing. Thus, in place of the friction being proportional to the pressure, it was found to be, within wide limits, almost independent of it. Mr. Tower discovered that in the case of a well-lubricated journal the metal surfaces never touch, being separated by a continuous film of oil. The fact thus established has led to a revolution in the practice of lubrication. For example, high-speed journals are now provided with a supply of oil out of all proportion to what would have been considered sufficient in the early seventies; and as a consequence the tool-marks are now often still visible on a journal which has made some millions of revolutions.

The adoption of forced lubrication, and the great extension which the system of ring lubrication has taken within recent years, may justly be considered as the outcome of Mr. Tower's researches. Mr. Tower had some difficulty in interpreting his results, as he held that, the friction in a well-lubricated journal being found to be wholly fluid friction, the coefficient should vary as the square of the linear velocity of the rubbing surfaces; but, as a matter of fact, it was found to increase much less rapidly. The explanation was provided by Professor Osborne Reynolds, whose experiments showed that up to a certain critical velocity, fluid friction varied directly as the velocity, and not as the square. In fact, once the friction begins to vary as the square of the velocity, the lubricant ceases to lubricate.

Perhaps the great disappointment of Mr. Tower's life was the failure of the Admiralty to adopt his "steady platform" for guns and search-lights at sea. By a most ingenious gyroscopic device Mr. Tower succeeded in maintaining within half a degree the horizontality of a gun-platform mounted on shipboard, in spite of the oscillations of the vessel. The device was tested by the Admiralty, who certainly encouraged the inventor to devote

his time to these experiments; but who, finally, in spite of the success of the trials, decided that the apparatus was unsuitable for the service. The principal reason given for this decision was that the weight needed for the "steady platform" could be more usefully employed in carrying an extra gun or extra ammunition. Though naturally disheartened by this unexpected rebuff, Mr. Tower proceeded to adapt his steady platform for use on cross-channel steamers, the idea being to provide "steady seats," and thus rob the Channel passage of its present terrors for the bad sailor. He was engaged in this work at the time of his death. W. H. B.

By the death of Dr. ALEXANDER W. WILLIAMSON, F.R.S., which occurred last year, the Society has to lament the loss of one of its most distinguished honorary members. Although the number of separate contributions which Williamson made to science was not by any means large, yet he exercised a remarkable influence on the development of Chemical Theory. The son of a clerk in the East India House, Williamson was born on May 1st, 1824. As a child, and throughout his boyhood his health was always delicate, although he ultimately grew up to vigorous manhood. One of his eyes, however, was permanently useless, and with the other his vision was very imperfect; also, his left arm was partially paralysed. As a practical chemist these physical disadvantages must have greatly interfered with his work, although, as Professor Thorpe remarks in his admirably appreciative obituary notice of Williamson (*Nature*, May 12th, 1904), this very limitation of his physical powers probably conduced to his eminence as a speculative thinker. Williamson was, for many years, Professor of Chemistry in University College, London, where he succeeded Graham. His reputation mainly rests upon what has been well called his "epoch-making" paper on the "Theory of Ætherification," which was published in 1850. In this paper he not only proved, by a series of admirable experiments, what are the real changes which occur during the ordinary process of

etherification, but he also showed the existence of a series of mixed ethers. These researches practically introduced into chemistry the "water-type," a theory which, although now merged in the more comprehensive modern theories of chemical constitution, was, in the hands of Williamson, wonderfully fascinating and fertile.

The doctrine of types was always the basis of Williamson's teaching. As a lecturer, especially on organic chemistry, he was unexcelled. The writer of this notice will never forget the delight with which he used to listen to Williamson's lectures on organic chemistry. At that time (in the early seventies) it was quite a common thing for the Demonstrators and Assistants in the laboratory, and even the Assistant Professors, to join the students in the Lecture Theatre, to hear once more the master's exposition.

Williamson occupied many important and honourable positions in connection with the Royal, the Chemical, and other Societies. He was President of the British Association at the Bradford meeting in 1873, and General Treasurer of that Association from 1874 to 1891. He was elected an honorary member of our Society in 1889. He retired from active work in 1887, living afterwards in such seclusion that he was practically unknown to the younger generation of chemical workers.

He died at his house at Hindhead, on May 6th, 1904.

R. L. T.

The Obituary Notice of Dr. GEORGE WILSON could not be prepared in time to be inserted here, and will therefore appear in the next volume.

NOTE.—The Treasurer's Accounts of the Session 1904-1905, of which the following pages are summaries, have been endorsed as follows:

April 11th, 1905. Audited and found correct.

We have also seen, at this date, the certificates of the following Stocks held in the name of the Society:—£1,225 Great Western Railway Company 5% Consolidated Preference Stock, Nos. 12,293, 12,294, and 12,323; £258 Twenty years' loan to the Manchester Corporation, redeemable 25th March, 1914 (No. 1564); £7,500 Gas Light and Coke Company Ordinary Stock (No. 6,389); and the deeds of the Natural History Fund, of the Wilde Endowment Fund, those conveying the land on which the Society's premises stand, and the Declaration of Trust.

Leases and Conveyance dated as follow:—

22nd Sept., 1797.
23rd Sept., 1797.
25th Dec., 1799.
" " "
22nd Dec., 1820.
23rd Dec., 1820.

Declarations of Trust:—

8th Jan., 1878.
24th June, 1801.
23rd Dec., 1820.
30th April, 1851.

We have also verified the balances of the various accounts with the bankers' pass books.

(Signed) R. S. HUTTON.
CHAS. OLDHAM.

Date of Election.

1904, Nov. 1. Stansfield, Herbert, B.Sc., A.I.E.E. *Eaglesfield, Victoria Park, Manchester.*

1894, Jan. 9. Stevens, Marshall, F.S.S. 18, *Exchange Street, Manchester.*

1905, May 2. Stopes, Marie C., B.Sc., Ph.D., Demonstrator of Botany in the University of Manchester. 11, *Kensington Avenue, Victoria Park, Manchester.*

1897, Nov. 30. Stromeyer, C. E., M.Inst.C.E. *Steam Users' Association,* 9, *Mount Street, Albert Square, Manchester.*

1905, Nov. 1. Sutcliffe, William Henry, F.G.S. *Shore, Littleborough, Lancs.*

1903, April 28. Sutton, Charles W., M.A., Librarian, *Free Reference Library, King Street, Manchester.*

1895, April 9. Tatton, Reginald A., M.Inst.C.E. Engineer to the Mersey and Irwell Joint Committee. 44, *Mosley Street, Manchester.*

1893, Nov. 14. Taylor, R. L., F.C.S., F.I.C. *Central School, Whitworth Street,* and 37, *Mayfield Road, Whalley Range, Manchester.*

1873, April 15. Thomson, William, F.R.S.E., F.C.S., F.I.C. *Royal Institution, Manchester.*

1896, Jan. 21. Thorburn, William, M.D., B.Sc. 2, *St. Peter's Square, Manchester.*

1896, Jan. 21. Thorp, Thomas, F.R.A.S. *Moss Bank, Whitefield, near Manchester.*

1899, Oct. 31. Thorpe, Jocelyn F., Ph.D., Demonstrator in Organic Chemistry in the Victoria University of Manchester. *The University, Manchester.*

1899, Oct. 17. Todd, William Henry. *Greenfield, Flixton, near Manchester.*

1873, Nov. 18. Waters, Arthur William, F.L.S., F.G.S. *Sunny Lea, Davos Dorf, Switzerland.*

1892, Nov. 15. Weiss, F. Ernest, D.Sc., F.L.S., Professor of Botany in the Victoria University of Manchester. 20, *Brunswick Road, Withington, Manchester.*

1903, Dec. 15. West, Norman, A.I.E.E., Electrical Engineer. 311, *Moss Lane East, Manchester.*

1895, April 9. Whitehead, James. *Lindfield, Fulshaw Park, Wilmslow, Cheshire.*

Date of Election.

1901, Oct. 1. Wild, Robert B., M.D., M.Sc., M.R.C.P., Professor of Materia Medica and Therapeutics in the Victoria University of Manchester. *Broome House, Fallowfield, Manchester.*

1859, Jan. 25. Wilde, Henry, D.Sc., D.C.L., F.R.S. *The Hurst, Alderley Edge, Cheshire.*

1901, Nov. 26. Wilson, William, M.A. *Carron Vale,* 80, *Fitzwarren Street, Pendleton, Manchester.*

1903, Oct. 20. Wood, Harry Edwin, B.Sc. *The Physical Laboratory, Owens College, Manchester.*

1902, Oct. 21. Woollcott, Walter. *Westinghouse Works, Trafford Park, Manchester.*

1860, April 17. Woolley, George Stephen. *Victoria Bridge, Manchester.*

1903, Nov. 17. Worthington, John Henry William, B.A., Assistant Master at the Manchester Grammar School. 60, *Filey Road, Fallowfield, Manchester.*

1863, Nov. 17. Worthington, Samuel Barton, M.Inst.C.E., M.I.Mech.E. *Mill Bank, Bowdon,* and 37, *Princess Street, Manchester.*

1865, Feb. 21. Worthington, Thomas, F.R.I.B.A. 46, *Brown Street, Manchester.*

1895, Jan. 8. Worthington, Wm. Barton, B.Sc., M.Inst.C.E. 2, *Wilton Polygon, Cheetham Hill, Manchester.*

1897, Oct. 19. Wyatt, Charles H., M.A., *Chelford, Cheshire.*

N.B.—Of the above list the following have compounded for their subscriptions, and are therefore life members:—

Bailey, Charles, M.Sc., F.L.S.
Bradley, Nathaniel, F.C.S.
Brogden, Henry, F.G.S.
Ingleby, Joseph, M.I.Mech.E.
Johnson, William H., B.Sc.
Worthington, Wm. Barton, B.Sc.

HONORARY MEMBERS.

Date of Election.

1892, April 26. Abney, Sir W. de W., K.C.B., D.Sc., F.R.S. *Rathmore Lodge, Bolton Gardens South, South Kensington, London, S.W.*

1892, April 26. Amagat, E. H., For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Examinateur à l'École Polytechnique. *Avenue d'Orléans*, 19, *Paris.*

1894, April 17. Appell, Paul, Membre de l'Institut, Professor of Theoretical Mechanics. *Faculté des Sciences, Paris.*

1892, April 26. Ascherson, Paul F. Aug., Professor of Botany. *Universität, Berlin.*

1889, April 30. Avebury, John Lubbock, Lord, D.C.L., LL.D., F.R.S. *High Elms, Down, Kent.*

1892, April 26. Baeyer, Adolf von, For. Mem. R.S., Professor of Chemistry. 1, *Arcisstrasse, Munich.*

1886, Feb. 9. Baker, Sir Benjamin, K.C.M.G., LL.D., F.R.S. 2, *Queen Square Place, Westminster, London, S.W.*

1886, Feb. 9. Baker, John Gilbert, F.R.S., F.L.S. 3, *Cumberland Road, Kew.*

1895, April 30. Beilstein, F., Ph.D., Professor of Chemistry. *8th Line, N. 17, St. Petersburg, W.O.*

1886, Feb. 9. Berthelot, Marcelin P. E., For. Mem. R.S., Membre de l'Institut, Professor of Chemistry, Secrétaire perpétuel de l'Académie des Sciences. *Paris.*

1892, April 26. Boltzmann, Ludwig, For. Mem. R.S., Professor of Physics. *Türkenstrasse 3, Vienna, IX. 1.*

1886, Feb. 9. Buchan, Alexander, M.A., LL.D., F.R.S., F.R.S.E. 42, *Heriot Row, Edinburgh.*

188 , April 17. Cannizzaro, Stanislao, For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Chemistry. *Reale Università, Rome.*

1889, April 30. Carruthers, William, F.R.S., F.L.S. 14, *Vermont Road, Norwood, London, S.E.*

1903, April 28. Clarke, Frank Wigglesworth, D.Sc. *United States Geological Survey, Washington, D.C., U.S.A.*

1866, Oct. 30. Clifton, Robert Bellamy, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy. 3, *Bardwell Road, Banbury Road, Oxford.*

Date of Election.

1892, April 26. Curtius, Theodor, Professor of Chemistry. *Universität, Kiel.*

1892, April 26. Darboux, Gaston, Membre de l'Institut, Professor of Geometry, Faculté des Sciences, Secrétaire perpétuel de l'Académie des Sciences. 36, *Rue Gay Lussac, Paris.*

1894, April 17. Debus, H., Ph.D., F.R.S. 4. *Schlangenweg, Cassel, Hessen, Germany.*

1888, April 17. Dewalque, Gustave, Professor of Geology. *Université, Liége.*

1900, April 24. Dewar, Sir James, M.A., LL.D., D.Sc., F.R.S., V.P.C.S., Fullerian Professor of Chemistry. *Royal Institution, Albemarle Street, London, W.*

1892, April 26. Dohrn, Dr. Anton, For. Mem. R.S. *Zoologische Station, Naples.*

1892, April 26. Dyer, Sir W. T. Thiselton, K.C.M.G., C.I.E., M.A., F.R.S., Director of the Royal Botanic Gardens. *Kew.*

1892, April 26. Edison, Thomas Alva. *Orange, N.J., U.S.A.*

1895, April 30. Elster, Julius, Ph.D. 6, *Lessingstrasse, Wolfenbüttel.*

1900, April 24. Ewing, James Alfred, M.A., F.R.S., Professor of Mechanism and Applied Mechanics. *Royal Naval College, Greenwich.*

1889, April 30. Farlow, W. G., Professor of Botany. *Harvard College, Cambridge, Mass., U.S.A.*

1900, April 24. Forsyth, Andrew Russell, M.A., Sc.D., F.R.S., Sadlerian Professor of Pure Mathematics. *Trinity College, Cambridge.*

1889, April 30. Foster, Sir Michael, K.C.B., M.P., M.A., M.D., LL.D., Sec. R.S., Professor of Physiology. *Trinity College, Cambridge.*

1892, April 26. Fürbringer, Max, Professor of Anatomy. *Grossherz. Universität, Jena.*

1900, April 24. Geikie, James, D.C.L., LL.D., F.R.S., Murchison Professor of Geology and Mineralogy. *Kilmorle, Colinton Road, Edinburgh.*

1895, April 30. Geitel, Hans. 6, *Lessingstrasse, Wolfenbüttel.*

1894, April 17. Glaisher, J. W. L., Sc.D., F.R.S., Lecturer in Mathematics. *Trinity College, Cambridge.*

1894, April 17. Gouy, A., Professor of Physics. *Faculté des Sciences, Lyons.*

Date of Election.

1900, April 24. Haeckel, Ernst, Ph.D., Professor of Zoology. *Zoologisches Institut, Jena.*

1894, April 17. Harcourt, A. G. Vernon, M.A., D.C.L., F.R.S., V.P.C.S. *St. Clare, Ryde, Isle of Wight.*

1894, April 17. Heaviside, Oliver, F.R.S. *Bradley View, Newton Abbot, Devon.*

1892, April 26. Hill, G. W. *West Nyack, N. Y., U.S.A.*

1888, April 17. Hittorf, Johann Wilhelm, Professor of Physics. *Polytechnicum, Münster.*

1892, April 26. Hoff, J. van't, Ph.D., For. Mem. R.S., Professor of Chemistry. 2, *Uhlandstrasse, Charlottenburg, Berlin.*

1892, April 26. Hooker, Sir Joseph Dalton, G.C.S.I., C.B., D.C.L., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.). *The Camp, Sunningdale, Berks.*

1869, Jan. 12. Huggins, Sir William, O.M., K.C.B., LL.D., D.C.L., P.R.S., F.R.A.S., Corr. Memb. Inst. Fr. (Acad. Sci.). 90, *Upper Tulse Hill, Brixton, London, S.W.*

1851, April 29. Kelvin, William Thomson, Lord, O.M., G.C.V.O., M.A., D.C.L., LL.D., F.R.S., F.R.S.E., For. Assoc. Inst. Fr. (Acad. Sci.). *Netherhall, Largs, Ayrshire.*

1892, April 26. Klein, Felix, Ph.D., For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Mathematics. 3, *Wilhelm Weber Strasse, Göttingen.*

1894, April 17. Königsberger, Leo, Professor of Mathematics. *Universität, Heidelberg.*

1892, April 26. Ladenburg, A., Ph.D., Professor of Chemistry. 3, *Kaiser Wilhelm Strasse, Breslau.*

1887, April 19. Langley, S. P., For. Mem. R.S. *Smithsonian Institution, Washington, U.S.A.*

1902, May 13. Larmor, Joseph, M.A., D.Sc., LL.D., Sec. R.S., F.R.A.S. *St. John's College, Cambridge.*

1892, April 26. Liebermann, C., Professor of Chemistry. 29, *Matthäi-Kirch Strasse, Berlin.*

1887, April 19. Lockyer, Sir J. Norman, K.C.B., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.). *Science School, South Kensington, London, S.W.*

1902, May 13. Lodge, Sir Oliver Joseph, D.Sc., LL.D., F.R.S., Principal of the University of Birmingham. *The University, Birmingham.*

1900, April 24. Lorentz, Henrik Anton, Professor of Physics. *Hooigracht,* 48, *Leyden.*

Date of Election.

1892, April 26. Marshall, Alfred, M.A., Professor of Political Economy. *Balliol Croft, Madingley Road, Cambridge.*

1892, April 26. Mascart, E. E. N., For. Mem. R.S., Membre de l'Institut, Professor at the Collège de France. 176, *Rue de l'Université, Paris.*

1889, April 30. Mendeléeff, D., Ph.D., For. Mem. R.S. *Université, St. Petersburg.*

1901, April 23. Metchnikoff, Élie, D.Sc., For.Mem.R.S. *Institut Pasteur, Paris.*

1895, April 30. Mittag-Leffler, Gösta, D.C.L. (Oxon.), For. Mem. R.S., Professor of Mathematics. *Djursholm, Stockholm.*

1892, April 26. Moissan, H., Membre de l'Institut, Professor of the Faculté des Sciences à la Sorbonne. 7, *Rue Vauquelin, Paris.*

1894, April 17. Murray, Sir John, K.C.B., LL.D., D.Sc., F.R.S. *Challenger Lodge, Wardie, Edinburgh.*

1894, April 17. Neumayer, Professor G., For. Mem. R.S., Director of the Seewarte. *Hohenzollern Strasse, 9, Neustadt an der Haardt, Germany.*

1887, April 19. Newcomb, Simon, For. Mem. R.S., For. Assoc. Inst. Fr. (Acad. Sci.), Professor of Mathematics and Astronomy. 1620, *P Street, Washington, D.C., U.S.A.*

1902, May 13. Osborn, Henry Fairfield, Professor of Vertebrate Palæontology. *Columbia College, New York, U.S.A.*

1894, April 17. Ostwald, W., Professor of Chemistry. 2/3, *Linnéstrasse, Leipsic.*

1899, April 25. Palgrave, R. H. Inglis, F.R.S., F.S.S. *Belton, Great Yarmouth.*

1892, April 26. Perkin, W. H., LL.D., Ph.D., F.R.S., V.P.C.S. *The Chestnuts, Sudbury, Harrow.*

1894, April 17. Pfeffer, Wilhelm, For. Mem. R.S., Professor of Botany. *Botanisches Institut, Leipsic.*

1892, April 26. Poincaré, H., For. Mem. R.S., Membre de l'Institut, Professor of Astronomy. 63, *Rue Claude Bernard, Paris.*

1892, April 26. Quincke, G. H., For. Mem. R.S., Professor of Physics. *Universität, Heidelberg.*

1899, April 25. Ramsay, Sir William, K.C.B., Ph.D., F.R.S., Professor of Chemistry. 12, *Arundel Gardens, Notting Hill, London, W.*

Date of Election.

1849, Jan. 23. Rawson, Robert, F.R.A.S. *Havant, Hants.*

1886, Feb. 9. Rayleigh, John William Strutt, Lord, O.M., M.A., D.C.L. (Oxon.), LL.D. (Univ. McGill), F.R.S., F.R.A.S., Corr. Memb. Inst. Fr. (Acad. Sci.). *Terling Place, Witham, Essex.*

1900, April 24. Ridgway, Robert, Curator of the Department of Birds, U.S. National Museum. *Brookland, District of Columbia, U.S.A.*

1897, April 27. Roscoe, Sir Henry Enfield, B.A., LL.D., D.C.L., F.R.S., V.P.C.S., Corr. Memb. Inst. Fr. (Acad. Sci.). 10, *Bramham Gardens, Earl's Court, London, S.W.*

1889, April 30. Routh, Edward John, D.Sc., F.R.S. *Newnham Cottage, Queen's Road, Cambridge.*

1894, April 17. Sanderson, Sir J. S. Burdon, Bart., M.A., M.D., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Regius Professor of Medicine in the University of Oxford. 64, *Banbury Road, Oxford.*

1902, May 13. Scott, Dukinfield Henry, M.A., Ph.D., F.R.S., F.L.S., Honorary Keeper of the Jodrell Laboratory, Royal Botanic Gardens, Kew. *Old Palace, Richmond, Surrey.*

1892, April 26. Sharpe, R. Bowdler, LL.D., F.L.S., F.Z.S. *British Museum (Natural History), Cromwell Road, London, S.W.*

1892, April 26. Solms, H., Graf zu, Professor of Botany. *Universität, Strassburg.*

1869, Dec. 14. Sorby, Henry Clifton, LL.D., F.R.S., F.L.S., F.G.S. *Broomfield, Sheffield.*

1886, Feb. 9. Strasburger, Eduard, D.C.L., For. Mem. R.S., Professor of Botany. *Universität, Bonn.*

1895, April 30. Suess, Eduard, Ph.D., For. Mem. R.S., For. Assoc. Inst. Fr. (Acad. Sci.), Professor of Geology. 9, *Africanergasse, Vienna.*

1895, April 30. Thomson, Joseph John, M.A., Sc.D., F.R.S., Professor of Experimental Physics. 6, *Scrope Terrace, Cambridge.*

1894, April 17. Thorpe, T. E., C.B., Ph.D., D.Sc., LL.D., F.R.S., V.P.C.S. *Government Laboratory, Clement's Inn Passage, Strand, London, W.C.*

Date of Election.

1894, April 17. Turner, Sir William, K.C.B., M.B., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy. 6, *Eton Terrace, Edinburgh.*

1886, Feb. 9. Tylor, Edward Burnett, D.C.L. (Oxon), LL.D. (St. And. and McGill Colls.), F.R.S., Professor of Anthropology. *Museum House, Oxford.*

1894, April 17. Vines, Sidney Howard, M.A., D.Sc., F.R.S., Sherardian Professor of Botany. *Headington Hill, Oxford.*

1894, April 17. Warburg, Emil, Professor of Physics. *Physikalisches Institut, Neue Wilhelmstrasse, Berlin.*

1894, April 17. Ward, H. Marshall, D.Sc., F.R.S., Professor of Botany. *Botanical Laboratory, New Museums, Cambridge.*

1894, April 17. Weismann, August, Professor of Zoology. *Universität, Freiburg i. Br.*

1886, Feb. 9. Young, Charles Augustus. *Hanover, New Hampshire, U.S.A.*

1888, April 17. Zirkel, Ferdinand, For. Mem. R.S., Professor of Mineralogy. *Thralstrasse*, 33, *Leipsic.*

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OF

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